



# Arctic Environmental Strategy

Government  
Publications

## Summary of Recent Aquatic Ecosystem Studies

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### Northern Water Resources Studies



Indian and Northern  
Affairs Canada

Affaires indiennes  
et du Nord Canada

Canada



## **Northern Water Resources Studies**

### **Arctic Environmental Strategy**

### **Summary of Recent Aquatic Ecosystem Studies**

**August 1995**

**Northern Affairs Program**

**Edited by**

**J. Chouinard**

**D. Milburn**



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## FOREWORD

The Arctic Environmental Strategy (AES), announced in April 1991, is a six-year \$100 million Green Plan initiative. The overall goal of the AES is to preserve and enhance the integrity, health, biodiversity and productivity of our Arctic ecosystems for the benefit of present and future generations. Four specific programs address some of the key environmental challenges: they are waste cleanup, contaminants, water management, and environment and economy integration. The programs are managed by the Northern Affairs Program of the Department of Indian Affairs and Northern Development (DIAND); however, there is a strong emphasis on partnerships with northern stakeholders including Native organizations, other federal departments and the territorial governments. The AES Action on Water Program specifically strives to enhance the protection of northern freshwaters through improved knowledge and decision-making. Water Resources managers in the Yukon and the Northwest Territories administer this Program which focuses on freshwater aquatic ecosystems.

This report is the first detailed compilation of studies conducted under the AES Action on Water Program. It covers work done from 1991 to 1994. Many studies have been concluded, while others are ongoing. Although data may not be available for all studies, or results are preliminary at this time, this report presents detailed background, objectives and methodology. At the end of the AES in 1997, a final report will summarize in detail all studies conducted under the Action on Water Program.

This report summarizes and also provides the reader with a detailed introduction to research and issues in northern freshwater ecosystem management. On behalf of Water Resources Division, Headquarters, I would like to extend my thanks to the regional Water Resources Division staff for their summaries and for their commitment to the Action on Water Program.

Chris Cuddy  
Chief  
Water Resources Division

## AVANT-PROPOS


Annoncée en avril 1991, la Stratégie pour l'environnement arctique (SEA) est un programme de 100 millions de dollars d'une durée de six ans, établi dans le cadre du Plan vert. L'objectif général de la SEA est de maintenir et d'améliorer l'intégrité, l'état, la biodiversité et la productivité de nos écosystèmes arctiques au profit de la génération actuelle et des générations futures. Quatre programmes particuliers sont consacrés à certains des principaux défis qui se posent sur le plan environnemental : l'élimination des déchets, les contaminants, la gestion de l'eau et l'intégration de l'environnement et de l'économie. Ces programmes sont gérés par le Programme des affaires du Nord du ministère des Affaires indiennes et du Nord canadien (MAINC); toutefois, on attache beaucoup d'importance à l'établissement de partenariats avec les intervenants du Nord, notamment les organismes autochtones, les autres ministères fédéraux et les gouvernements territoriaux. Établi dans le cadre de la SEA, le Programme d'action sur l'eau vise particulièrement à mieux protéger les eaux douces du Nord grâce à une meilleure connaissance sur le sujet et à la prise de décisions. Les gestionnaires des ressources en eau dans le Yukon et les Territoires du Nord-Ouest administrent ce programme, qui met l'accent sur les écosystèmes d'eaux douces.

Le présent rapport est la première compilation détaillée d'études menées dans le cadre du Programme d'action sur l'eau. Il porte sur les travaux effectués de 1991 à 1994. De nombreuses études ont été menées à bien, mais d'autres sont toujours en cours. Bien que les données ne soient peut-être pas disponibles pour toutes ces études ou que les résultats soient préliminaires en ce moment, le rapport fournit des renseignements sur la situation générale, les objectifs et les méthodes. Lorsque la SEA prendra fin, en 1997, un rapport final sera présenté résumant en détail toutes les études effectuées dans le cadre du Programme d'action sur l'eau.

Ce rapport-ci présente un résumé et une introduction détaillée sur la recherche et les questions concernant la gestion des écosystèmes d'eaux douces dans le Nord. Au nom de la Division des

ressources hydrauliques, administration centrale, j'aimerais ici remercier le personnel régional de la Division pour ses résumés et pour son engagement à l'égard du Programme d'action sur l'eau.

Le chef,  
Chris Cuddy  
Division des ressources hydrauliques



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## PREFACE

This report consists of summaries of research studies conducted under the Action on Water Program of the AES from 1991 to 1994. The studies address a wide range of water issues including community health concerns about drinking water quality, flood forecasting, fish population levels and the efficiency of sewage treatment facilities and tailings ponds. Many studies respond directly to concerns or issues raised by northern residents and industry.

Studies are grouped according to five broad subject areas: aquatic ecosystem evaluation, community health issues, sustainable development issues, predictions, forecasts and models, and education. They are all funded in whole, or in part, under the area-specific studies portion of the Action on Water Program. For the most part, the studies were conducted by staff members of regional DIAND Water Resources Divisions. A small number were contracted out. In addition, many studies were co-funded with other agencies. These studies represent only part of the activities conducted under the Program. Other important components are baseline networks and laboratory facilities. The AES presently funds 61 quality and 21 quantity stations and five snow stations in the Northwest Territories (NWT). The Yukon has 20 quality and 12 quantity stations and an additional small stream water quantity network of 11 stations. The Yukon has 45 snow quantity stations, some of which are automated snow pillow stations.

To increase the information on northern water resources and achieve the goals of the Action on Water Program, the data are now being interpreted and evaluated. Network expansion and data collection have been extensive during the first three years. Network data are used for many purposes including environmental assessments and remediation, and for predicting and monitoring floods. Baseline data from these stations also establish background conditions and identify areas where further research is warranted.

The AES Action on Water Program has been tremendously successful in responding to emerging issues in the field of northern freshwater ecosystem management. This report provides interested readers with an indication of the type of research being conducted, as well as good

background information on northern water issues. Initially, a report with brief study descriptions was considered, but as the project evolved the need for detailed summaries, data presentation and interpretation became evident. Each study or project co-ordinator was asked to provide information in the standardized format used in this report. We wish to thank them. For consistency, original material has been rearranged and text inserted.

J. Chouinard and D. Milburn, Editors  
Water Resources Division  
Department of Indian Affairs and Northern Development  
Ottawa, Ontario  
K1A 0H4

## PRÉFACE

Le présent rapport présente des résumés des études de recherche effectuées de 1991 à 1994 dans le cadre du Programme d'action sur l'eau de la SEA. Ces études portent sur une gamme variée de questions concernant l'eau, notamment les préoccupations exprimées par les collectivités en ce qui a trait à la qualité de l'eau potable, la prévision des inondations, les niveaux des peuplements de poissons et l'efficacité des installations de traitement des eaux usées ainsi que des bassins de décantation et de stockage des stériles et boues. De nombreuses études découlent directement des préoccupations exprimées ou des questions soulevées par des résidents du Nord ou par l'industrie.

Les études sont groupées selon cinq grands domaines : l'évaluation des écosystèmes aquatiques, les questions de santé communautaire, les questions de développement durable, les prévisions et les modèles, et l'éducation. Elles sont toutes financées, entièrement ou en partie, dans le cadre de projets sur des domaines particuliers. Dans la plupart des cas, ces études ont été menées par les membres du personnel des Divisions régionales des ressources hydrauliques du MAINC. Un petit nombre ont été confiées à des entrepreneurs. En outre, de nombreuses études ont été cofinancées par d'autres organismes. Ces études ne représentent qu'une partie des activités réalisées dans le cadre de ce programme, les réseaux de base et les installations de laboratoire étant d'autres composantes importantes. La SEA finance actuellement 61 stations de contrôle de la qualité de l'eau, 21 stations de mesure de la quantité d'eau et cinq stations de mesure de la quantité de neige dans les Territoires du Nord-Ouest (T. N.-O.). Le Yukon compte 20 stations de contrôle de la qualité de l'eau et 12 stations de mesure de la quantité d'eau, ainsi qu'un autre réseau de mesure de la quantité d'eau dans les petits ruisseaux, qui comprend 11 stations. Le Yukon compte 45 stations de mesure de la quantité de neige, dont certaines sont des stations automatisées dotées de coussins à neige.

Pour accroître le volume d'informations sur les ressources en eau dans le Nord et atteindre les objectifs du Programme d'action sur l'eau, les données sont maintenant interprétées et évaluées.

L'expansion des réseaux et la cueillette de données ont été importantes au cours des trois premières années. Les données provenant des réseaux sont utilisées à bien des fins, notamment

les évaluations environnementales, la prise de mesures correctives, ainsi que la prédiction et la surveillance des inondations. Les données de référence provenant de ces stations permettent également de déterminer les conditions ambiantes et indiquent les domaines où d'autres recherches sont justifiées.

Le Programme d'action sur l'eau connaît beaucoup de succès pour ce qui est d'apaiser les préoccupations naissantes concernant la gestion des écosystèmes d'eaux douces dans le Nord. Le présent rapport fournit une indication du genre de recherche effectuée ainsi que de bonnes informations générales sur les questions concernant l'eau dans le Nord. Au début, nous avions l'intention de produire un rapport présentant une brève description des études, mais à mesure que le projet a évolué, il est devenu évident qu'un rapport avec des résumés détaillés et une interprétation des données s'imposait. Nous avons demandé à chaque coordonnateur d'étude ou de projet de fournir des informations en respectant le format normalisé utilisé dans ce rapport-ci. Nous tenons ici à les remercier. À des fins d'uniformisation, nous avons remanié les documents originaux et inséré des textes.

J. Chouinard et D. Milburn, réviseurs  
Division des ressources hydrauliques  
Affaires indiennes et du Nord Canada  
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## 1.0 INTRODUCTION

The AES Action on Water Program addresses current and emerging water issues in northern freshwater ecosystems. The issues can be as simple as answering basic questions such as "Can we eat the fish?" and "Can we drink the water?" or as complex as determining northern ecosystem response to upstream, out-of-territory developments such as pulp mills. Because many residents still rely on the aquatic environment for their subsistence lifestyle, these concerns are paramount. The studies are, for the most part, identified by Northerners and their success is based largely on the cooperation of other government departments, industry, First Nations and other northern residents.

Over the years the Program has evolved and has become more dynamic and responsive to local concerns. Where possible, Aboriginal residents are involved in the study design and implementation. After four years, the Program has resulted in significant improvements in the knowledge of northern freshwater ecosystem issues.

The summaries of recent aquatic ecosystem studies have been organized in five broad subject areas. The first section consists of aquatic ecosystem evaluation studies. These studies focus on the evaluation of ecosystem health and are concerned with both biotic and abiotic components. Also included are monitoring studies which establish spatial and temporal trends.

The second section deals with community health issues, specifically the potential effects of human settlements on health. This section addresses concerns that have direct impacts on the quality of life.

Sustainable development issues are the third section. Mineral development is the leading industry in Canada's North. It accounts for over 30% of the value of all goods and services. Although only a small percentage of the work force is directly employed in mining, the industry brings significant economic benefits. Mining can also cause detrimental ecosystem effects. This

section contains studies that address the balance between promoting economic development and protecting freshwater ecosystems.

The fourth section - predictions, forecasts and models - consists of two studies, one describing an update of a flood database and the second, a method for correcting precipitation estimates. Because of the potential loss of life and infrastructure, sound knowledge of potential flood events is important in vulnerable areas.

The final section of this report consists of two education studies. Improved resource management requires a solid understanding of resources. To achieve this end, a manual has been developed for high school teachers in the NWT and a video for municipalities on the rationale and methods of water treatment.

## **2.0 AQUATIC ECOSYSTEM EVALUATION**

### **2.1 SLAVE RIVER ENVIRONMENTAL QUALITY MONITORING PROGRAM<sup>1</sup>**

#### **PROJECT COORDINATOR**

J.D. Peddle  
Water Resources Division  
Indian and Northern Affairs Canada  
Yellowknife, NWT

#### **PROJECT OBJECTIVES**

1. To provide baseline data on contaminant levels in water, sediment and fish at the Alberta and NWT boundary to support transboundary water negotiations;
2. To detect and quantify changes in environmental quality of the aquatic ecosystem over time; and
3. To address the concerns of NWT residents regarding possible impacts from upstream development (particularly in association with pulp and paper, hydrocarbon production, agriculture and forest management) on their continued ability to drink the Slave River water and eat Slave River fish.

#### **DESCRIPTION**

The Slave River supplies 87% of the total annual discharge to Great Slave Lake. It combines the outflow of the Lake Athabasca and Peace River basins and flows 415 kilometres in a northwest direction from the Peace Athabasca delta to Great Slave Lake. The Slave River is a transboundary river; it drains an area of approximately 600,000 km<sup>2</sup>, nearly all of which is located in the provinces of Alberta, British Columbia and Saskatchewan. The NWT portion of the river basin is located downstream of all three jurisdictions. This portion of the Slave Basin is important as a direct source of drinking water and as an aquatic environment. It is important to several aspects of a northern subsistence lifestyle because it provides habitat for wildlife species,

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<sup>1</sup>Editors' Note: This summary is adapted from a poster presented at the Second International Conference on Environmental Fate and Effects of Bleached Pulp Mill Effluent, Vancouver, November 6-10, 1994 and at the Society of Canadian Limnologists Annual Conference, Ottawa, January 5-7, 1995.

including fish, and is culturally and spiritually significant.

### **Sampling Program**

The Slave River Environmental Quality Monitoring Program was designed as a multimedia transboundary sampling program to characterize the baseline aquatic ecosystem conditions in the Slave River at Fort Smith, NWT (MacDonald 1990). The five-year program began in 1990. The program is a cooperative venture among the Government of the Northwest Territories, Indian and Northern Affairs Canada, Fisheries and Oceans Canada and Environment Canada. Funding for the program is provided by the AES Action on Water Program and the Government of the Northwest Territories.

Water, suspended sediment and fish samples were collected for organic and inorganic contaminant analyses including dioxin, furan and other organochlorines. Stable isotope work and delta sediment coring were also carried out in conjunction with this study.

Fish species were selected based on several factors including their presence and residency time in the Slave River, their importance to human consumers, their potential to accumulate contaminants, their trophic level and their degree of exposure to the sediment. Muscle, bile, liver and/or whole fish samples were prepared for each species. Whole fish analysis provides an indication of the availability of contaminants at a trophic level. Burbot liver tissue samples were also analyzed because they are part of a subsistence diet. The relatively high lipid content of the livers leads to greater accumulation of lipophilic chlorinated organic contaminants (Voss and Yunker, 1983). In addition, the liver is a detoxifying organ and acts as a filter, making it a major site for the deposition of any toxic compounds in the fish.

Suspended sediment was collected as many pollutants of concern are known to adsorb to small sized sediment particles (Allan, 1986). In a fast flowing river such as the Slave, these particles remain suspended in the water column for a long period before sinking to the bottom of the river. Water samples were analyzed to address Northerners' concerns about safe drinking water and as part of transboundary water negotiations.

## **Sampling Sites**

Water, sediment and fish were sampled from the Slave River at Fort Smith, NWT below the Rapids of the Drowned. Two control sites were selected: Leland Lake for walleye (*Stizostedion vitreum*), pike (*Esox lucius*) and whitefish (*Coregonus clupeaformis*); and Chitty Lake for burbot (*Lota lota*) (Figure 1). These watersheds are not developed and provide the necessary fish species, sizes and numbers.

No control sites were selected for water and sediment samples. Water blanks and Standard Reference Materials provided for quality control.

## **Field Methods**

### Fish

Walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*) and lake whitefish (*Coregonus clupeaformis*) were collected in gill nets (mesh sizes of 89 and 114 mm and lengths of 23 or 46 m) in September of each year. Burbot (*Lota lota*) were caught with baited hooks set under the ice in December. Biological data (weight, fork length, sex, gonad maturity and gonad weight) were recorded for each fish and the appropriate ageing structures were removed.

### Water and Sediment

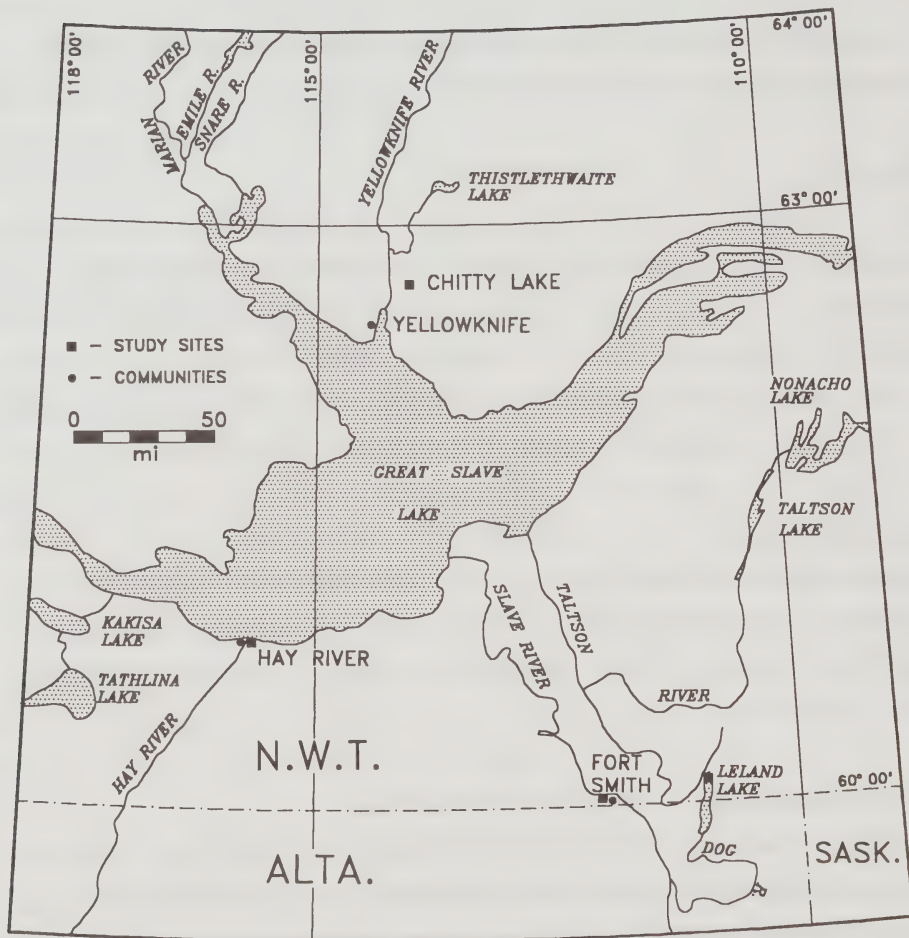
Grab water samples were collected monthly. Centrifugate water and suspended sediment samples were collected using a Sedi-Samp II Continuous Flow Centrifuge. Samples were collected four times a year to allow for representative sampling according to the hydrologic cycle.

## **Analytical Methodology for Dioxin and Furan Samples**

All fish samples were shipped whole on dry ice in food grade resin plastic bags. All samples were blended with sodium sulphate, packed in glass columns and eluted with methylene chloride. Lipids were removed from samples via gel permeation chromatography. Alumina and silica gel columns were used to further clean up PCDD/PCDF. Analysis and quantification was by GC-high resolution mass spectrometry.

# Figure 1

## Map of Field Sampling Sites



## RESULTS AND DISCUSSION

Water and sediment data for the past four years (1990-1994) consist mainly of values that are below detection limits, in spite of the change in detection limits as the result of improved analytical methods and a change in laboratories in 1992. A preliminary summary of these data is presented in Table 1. Further interpretation is pending. Results suggest that contaminant levels in water and sediment in the NWT portion of the Slave River are low compared to similar studies in Canada.

### **Fish - Dioxin and Furan**

Preliminary results for dioxin and furan in walleye and burbot from both the Slave River and the control sites are presented in Figures 2 - 9. Burbot livers were also analyzed from 1988 to 1990 as part of a pilot study. Data are, for the most part, below detection. This, together with multiple detection limits (the result of improved analytical methods and differences in laboratory techniques) have restricted statistical analysis. These issues are presently being addressed; however, preliminary analysis is made with time-based scattergrams.

In walleye, 2,3,7,8 TCDD and 2,3,7,8 TCDF isomers made up 100% of the total TCDD (dioxin) and TCDF (furans) detected. This is generally true for the 2,3,7,8 TCDF isomer in burbot liver.

Furan levels are approximately five times higher than dioxin levels in burbot liver from the Slave River. Routinely, tetra furan isomer levels in whole fish samples are anywhere from 2 to 10

**Table 1. Summary of water, sediment and fish data for the Slave River Environmental Monitoring Program.**

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**Water:**

EOCLs	Levels were below detection limits of 0.5 - 2.0 $\mu\text{g/L}$
Chlorophenols	Detection limits for chlorophenols ranged from 0.0001 - 0.02 $\mu\text{g/L}$ . Levels generally below detection limits.
Herbicides	Herbicides analyzed were 2,4-D, 2,4,5-T and MCPA. Levels were below detection limits of 0.0003 $\mu\text{g/L}$ - 0.2 $\mu\text{g/L}$ .
PAHs	Levels were below detection limits of 0.13 ng/L - 3.0 $\mu\text{g/L}$ . Detection limits varied for each parameter analyzed.
Metals:	Results have not been summarized.

**Sediment:**

EOCLs	Levels below detection limit of 0.5 $\mu\text{g/g}$ .
Chlorophenols	Detection limits of 0.05 - 20.0 ng/g. Most levels were below detection limits.
Pesticides	Levels below detection limits of 0.2 - 50 ng/g.
PAHs	The detection limit was different for each of the parameters analyzed. From 1990 to 1994 the detection limit varied from 0.003 - 0.01 $\mu\text{g/g}$ . After 1992, a greater proportion of results were above detection limits.
OC Scan	Detection limits varied from 0.001 - 0.5 $\mu\text{g/g}$ and for each parameter. Levels were below detection limits.
Dioxin/ Furan	Levels were below detection limit of 0.1 - 3.0 pg/g.
Metals	Results have not been summarized.

**Fish:**

MFOs	EROD, AHH, and P-450 enzyme activities were measured in liver tissue from all species. The data are presently being interpreted.
Chlorophenols/ EOCLs/OC Scan	Results have not been summarized.
PAHs	Results have not been summarized.
Metals	Results have not been summarized.

---

times higher than tetra dioxin isomer concentrations at sites where the major source of contamination is suspected to originate from bleached kraft mill discharges (Whittle, 1989).

The dioxin and furan levels in walleye whole fish are similar in the Slave River and the control lake (Figures 2-5). Concentrations in burbot liver are more elevated in the Slave River samples (Figures 6-9).

The detection of TCDD and TCDF isomers in fish suggests not only the presence of these compounds in the Slave River ecosystem, but that they are also bioavailable. Concentrations are greater in burbot liver samples than in walleye whole fish samples. This may be explained by the greater percentage of lipid in burbot liver compared to walleye whole fish.

## **CONCLUSIONS**

The Slave River Environmental Quality Monitoring Program was designed to provide baseline data on levels of contaminants in the Slave River and to determine impacts on water use and fish populations from upstream development. These goals are being met.

From a preliminary examination of the data, it appears that the environmental quality of the Slave River at Fort Smith, NWT, Canada is relatively unimpaired. With this extensive database, it will be possible to detect and quantify any changes in ecosystem quality.

Figure 2

## Furan Levels in Walleye Wholefish from the Slave River

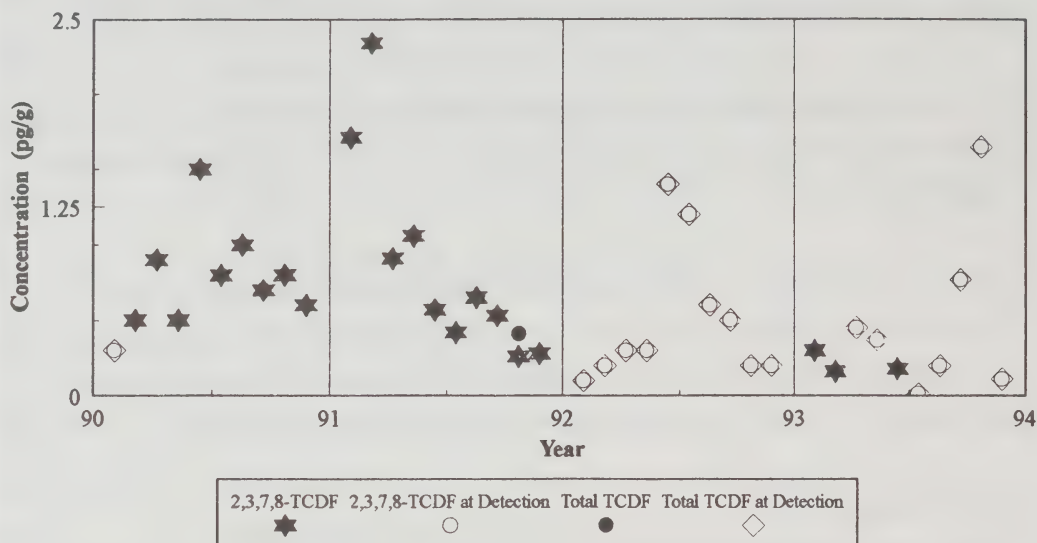


Figure 3

## Furan Levels in Walleye Wholefish from Leland Lake (Control)

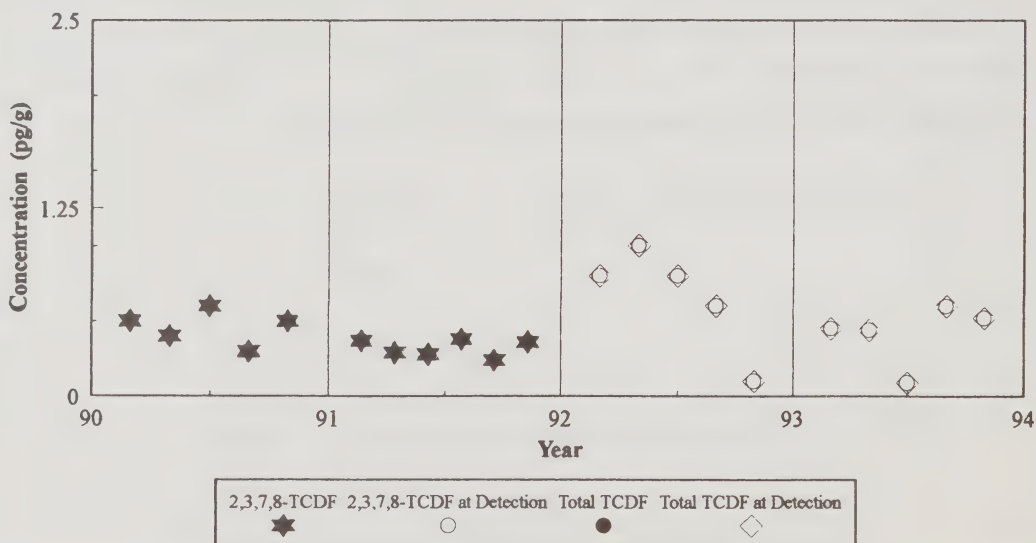


Figure 4 Dioxin Levels in Walleye Wholefish from the Slave River

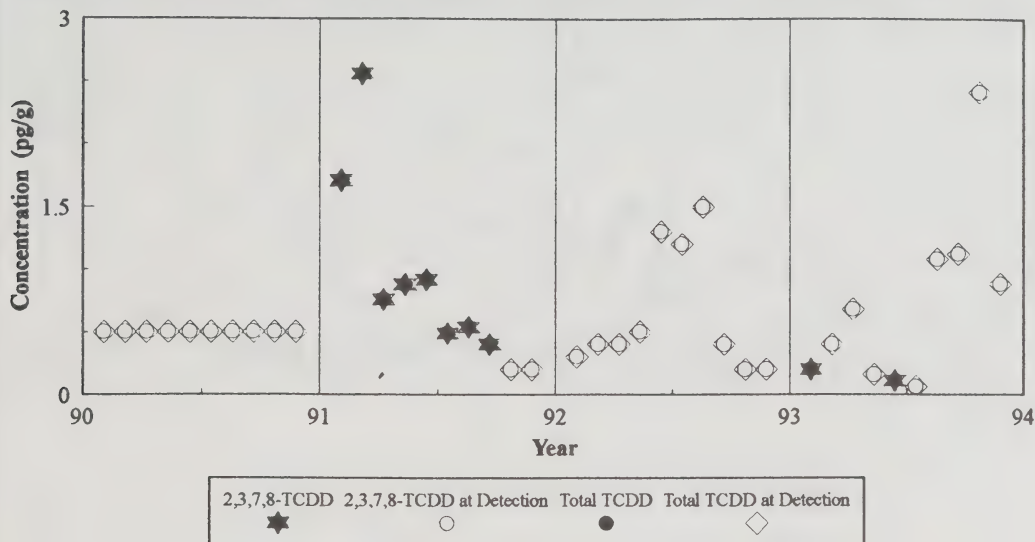


Figure 5 Dioxin Levels in Walleye Wholefish from Leland Lake (Control)

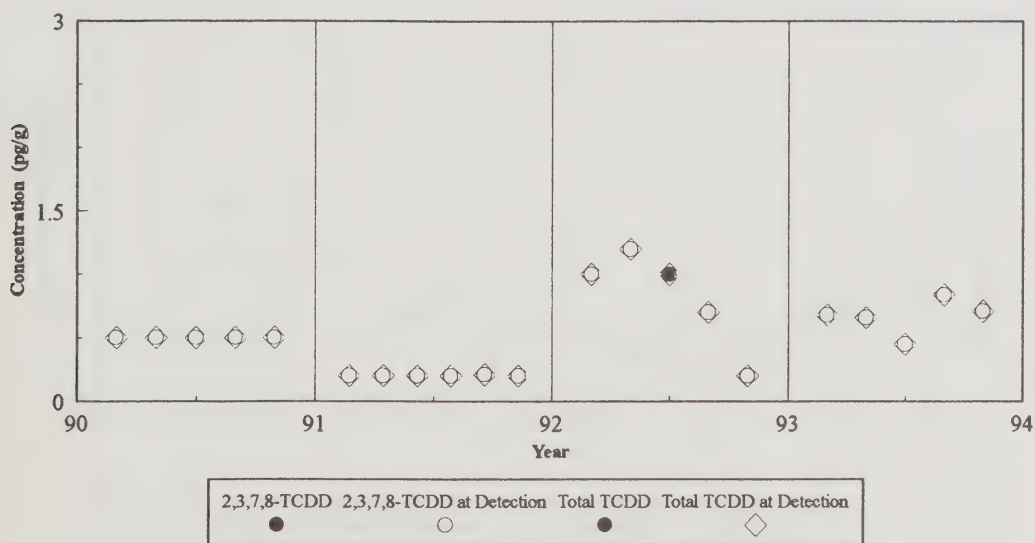


Figure 6

# Dioxin Levels in Burbot Liver from Slave River

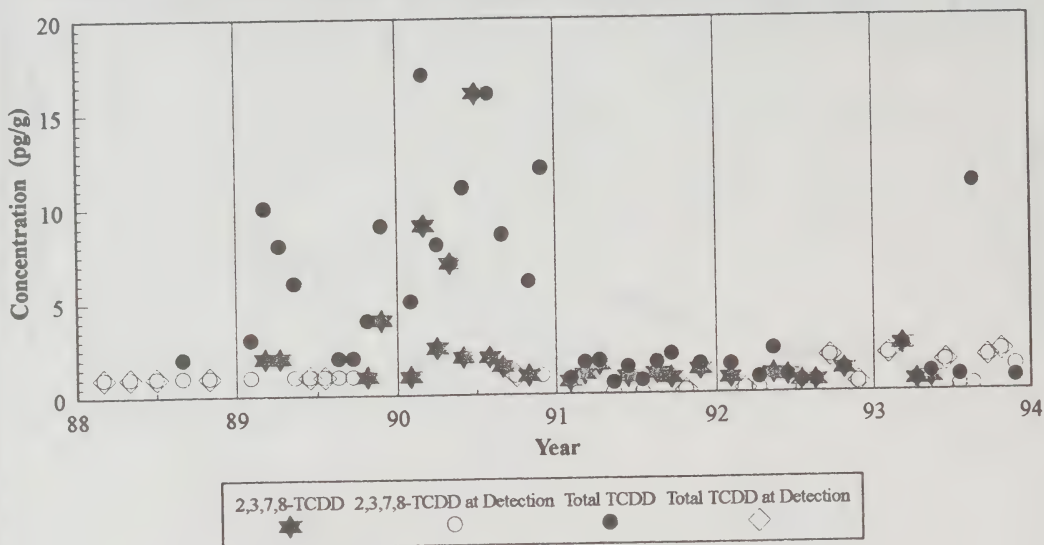


Figure 7

# Dioxin Levels in Burbot Liver from Chitty Lake (Control)

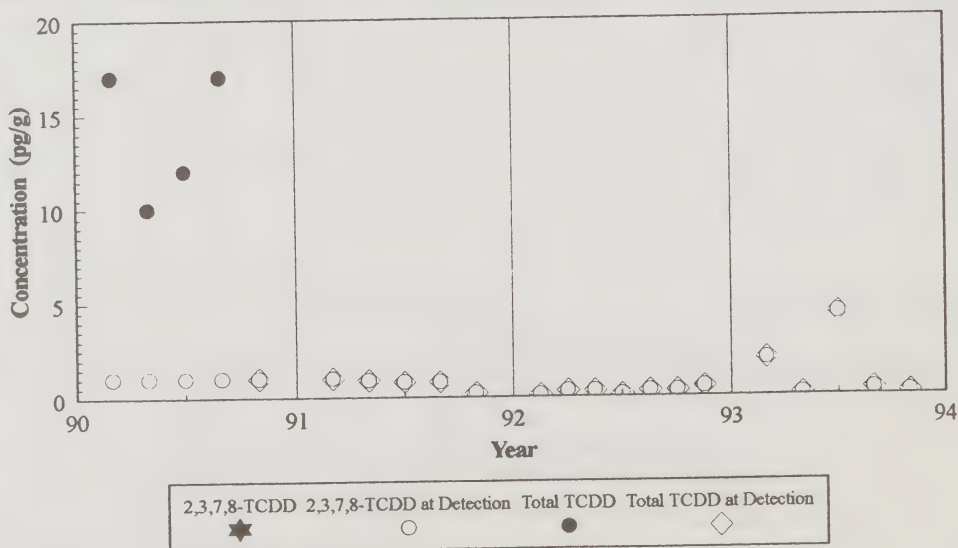


Figure 8. Furan Levels in Burbot Liver from the Slave River

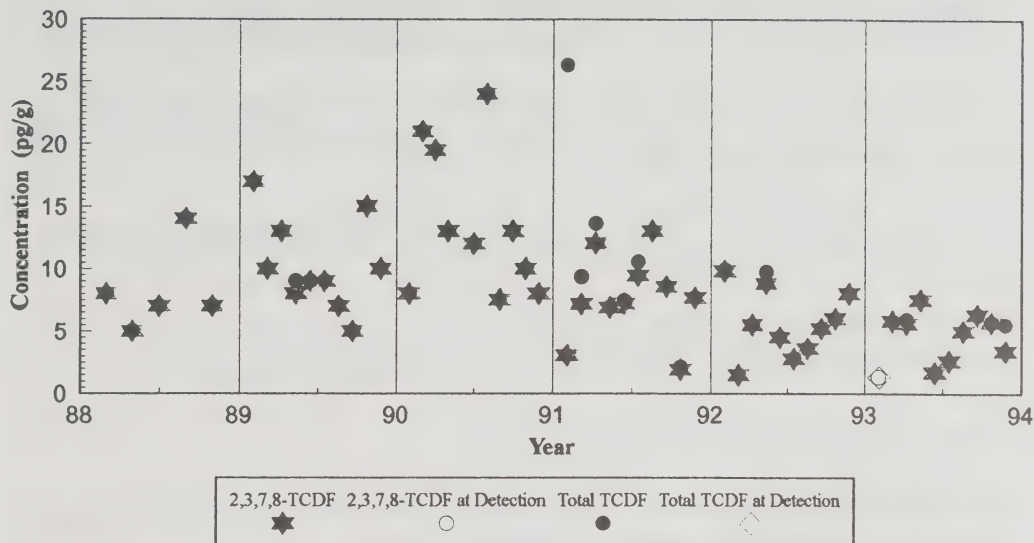
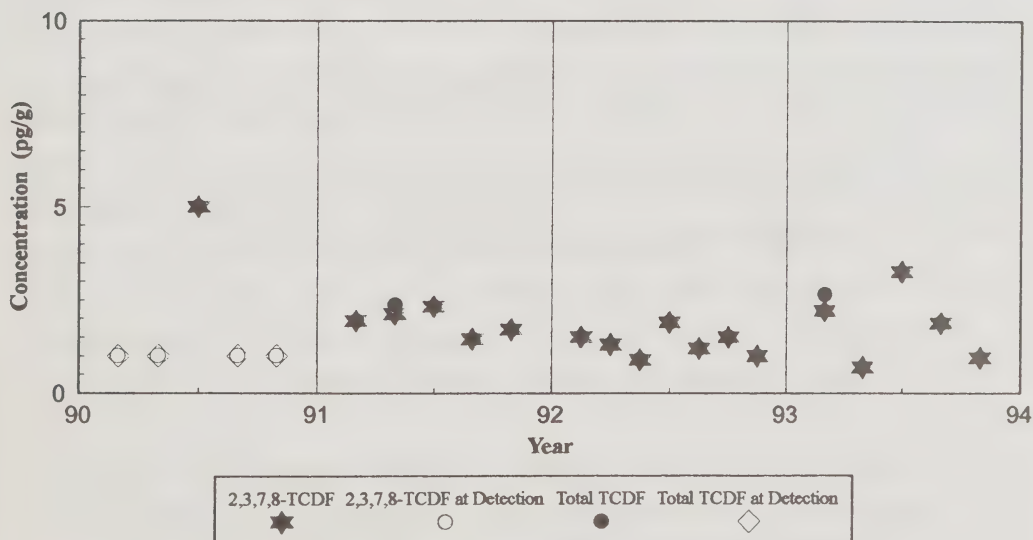


Figure 9. Furan Levels in Burbot Liver from Chitty Lake (Control)



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## **2.2 LIARD RIVER ENVIRONMENTAL MONITORING PROGRAM**

### **PROJECT COORDINATOR**

J. Peddle  
Water Resources Division  
Indian and Northern Affairs Canada  
Yellowknife, NWT

### **PROJECT OBJECTIVES**

1. To characterize baseline quality conditions for fish, water, suspended sediment and benthic invertebrates of the Liard River at Fort Liard with specific attention to contaminant levels of organochlorines, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), toxaphene and trace metals; and
2. To understand potential impacts of water uses and fish populations due to upstream development in the Liard River basin that have been raised by local residents.

### **DESCRIPTION**

The Liard River and its tributaries drain an area of approximately 270,000 km<sup>2</sup>. The river rises in the Pelly Mountains of the Yukon and flows southeast into British Columbia where it is joined by the Fort Nelson River, and then flows north and meets the Mackenzie River at Fort Simpson. Mean annual discharge at Fort Liard (Water Survey of Canada Station 10ED001) is 1,970 m<sup>3</sup>/sec. Because the Liard River crosses two provincial-territorial boundaries, concerns have been raised by residents of the NWT about the potential for transboundary pollution that originates in upstream jurisdictions. DIAND, through the Mackenzie River Basin Committee, is negotiating transboundary water agreements between British Columbia and Yukon, and British Columbia and the NWT. A critical element of these negotiations is understanding baseline conditions at transboundary crossings.

The Liard River Environmental Monitoring Program was designed to characterize baseline conditions of the aquatic ecosystem with particular attention to fish, water and suspended sediment, and to address concerns about possible impacts of potential upstream

developments such as mining, logging, oil, gas and hydroelectric developments. Sampling was conducted at the Liard River upstream of the Kotaneelee River near the community of Fort Liard. For comparison purposes, Cormack Lake was selected as a control site for the fish analysis.

The Environmental Monitoring Program consists of two distinct components, a basin assessment study and a field monitoring program.

- 1) Basin Assessment Study: to ensure that the transboundary water management agreements are based on sound information, a contract was let in 1992 to MacDonald Environmental Sciences Ltd. (MESL) to conduct a regional assessment of the Liard River basin. The study report, which was distributed to a wide audience, summarizes available information on existing and potential water uses, synthesizes information on the ambient environmental conditions of the river and identifies gaps in knowledge (MESL, 1992). Finally, the study examined proposed and current basin activities to understand potential detrimental effects.
- 2) Field Monitoring Program: the basin assessment study was used to design an environmental quality monitoring program comprising water, suspended sediment and fish sample collections from a site on the Liard River above the Kotaneelee River. The study design is based on sampling various media and analyzing a number of parameters that could be associated with potential upstream developments. The monitoring program will characterize the baseline aquatic environment conditions of the NWT portion of the Liard River basin and enable assessments of changes to be made in the future.

### **Summary of Sampling Program**

A sampling program was conducted in June and August 1992 and March, June and August 1993. Water samples were analyzed for a number of parameters including total organic carbon, total nitrogen, physical parameters, trace metals, nutrients and major ions (Table 1a).

Suspended sediment samples were also analyzed for trace metals and nutrients, and a range of PAHs and organochlorines (Table 1b).

**Table 1a.**  
**Parameter list for water quality samples**

Routine	Nutrients	Metals	Sulphides
pH Specific conductance Colour Alkalinity Calcium Magnesium Sodium Potassium Chloride Sulphate Total hardness	Turbidity Non-filterable residue (TSS) Filterable residue (TDS) Nitrate and nitrite Ammonia Total phosphorous	Total Arsenic Total Cadmium Copper Chromium Cobalt Iron Lead Mercury Nickel Zinc	Sulphides

**Table 1b.**  
**Parameter list for sediment samples**

Metals		Polyaromatic hydrocarbons	Organochlorines
Aluminum Antimony Arsenic Barium Beryllium Bismuth Boron Cadmium Calcium Copper Chromium Cobalt Iron Lead	Magnesium Manganese Mercury Molybdenum Nickel Potassium Selenium Silver Sodium Tin Titanium Vanadium Zinc	Acenaphthene Acenaphthylene Anthracene Fluorene Methyl naphthalenes Naphthalene Phenanthrene Benzo(a)anthracene Benzo(a)pyrene Chrysene Dibenzo(a,h)anthracene Fluoranthrene Pyrene	Hexachlorobenzene Pentachlorobenzene Chlordane DDT DDE DDD Dieldrin Hexachlorocyclohexane Mirex Photomirex Polychlorinated biphenyls Toxaphene

Walleye, pike, longnose sucker and lake whitefish were collected from the Liard River from a total of eight sites. Muscle and liver tissue, as well as bile and whole fish samples were prepared for analysis. In addition to basic biological data, the samples will be analyzed for PCBs, toxaphene, pesticides, chlorobenzenes and other organochlorines, PAHs and trace metals. Bile samples of the fish will also be analyzed for concentrations of mixed function oxidase (MFO). MFO analysis was included to gauge the stress level of the fish. Typically, organisms will have increased concentrations of this enzyme in response to chemical stress. Collection of benthic invertebrate samples for PAH analyses was also intended but sampling was unsuccessful.

A prospective control site was selected at Bluefish Lake in conjunction with the Department of Fisheries and Oceans, but this site was discontinued because of low fish populations. An alternate site, Cormack Lake, was selected and will be sampled in the next year.

## **PRELIMINARY RESULTS**

### **Water Quality Program**

Physical parameters and nutrient concentrations in water quality samples are in the range expected for pristine northern rivers. Hardness falls generally within a range of 100 - 200 mg/L, while pH reports consistently at 7.9 - 8.2. During low flow periods, specific conductance ranges from 200 - 280  $\mu\text{S}/\text{cm}$ . During peak flow, the values rise to over 400  $\mu\text{S}/\text{cm}$ . With the exception of two anomalous results from March 1992, the concentrations of nitrite and nitrate, total ammonia and total phosphorous are all within the Canadian Water Guidelines for freshwater aquatic life.

Concentrations of metals and trace elements are also consistent with pristine northern rivers and generally fall within the Canadian Water Guidelines for freshwater aquatic life. Total iron is the only metal that exceeds these guidelines; however, measured concentrations are closely tied to suspended sediment concentrations and it is known that iron is released naturally into aquatic ecosystems from weathering of igneous, sedimentary and metamorphic rocks. Concentrations of other metals such as total copper and total zinc are

closely linked to the annual hydrograph; that is, concentrations increase with increasing streamflow (Figures 1a and 1b). These results show the relationship of select metals to suspended sediment transport.

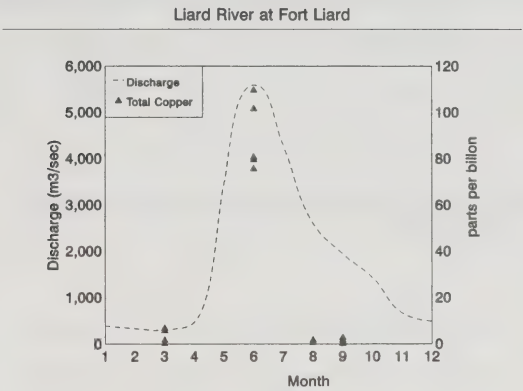


Figure 1a. Total Copper, 1992 and 1993 data.

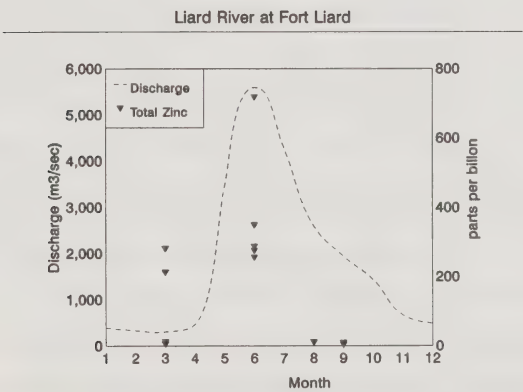


Figure 1b. Total Zinc, 1992 and 1993 data.

## Suspended Sediment Program

Suspended sediment collected by centrifuge was analyzed for a suite of PAHs, organochlorines and metals. Of the PAHs, only methynaphthalenes, naphthalene and phenanthrene consistently report above detection limits in all samples (Table 2). Chrysene, fluoranthrene and pyrene are reported in four of five samples analyzed. These preliminary results have not been assessed in terms of potential impacts to the aquatic ecosystem. No measurable concentrations of any analyzed organochlorines were reported.

**Table 2.**

**Mean concentrations of PAHs detected in Liard River sediments. Results are reported in parts per billion dry weight.**

	Mean	Range	n
Methyl naphthalenes	0.101	0.034 - 0.32	5
Napthalene	0.063	0.017 - 0.10	5
Phenanthrene	0.070	0.035 - 0.12	5
Chrysene	0.035	0.017 - 0.05	4
Fluoranthrene	0.014	0.009 - 0.02	4
Pyrene	0.022	0.015 - 0.03	4

Three samples of sediment were analyzed for a suite of metals. Concentrations of aluminium, calcium, iron, magnesium and manganese are significantly greater than the detection limit. A preliminary assessment of these findings is that the source of sediment is likely naturally occurring fine-grained limestone or dolomitic material. Metals such as aluminum, copper, lead and zinc that can have environmental effects are consistently above detection limits, while total mercury ranges from 0.011 ug/L - 0.068 ug/L (Table 3).

**Table 3.**

**Mean concentrations of select metals in Liard River sediments. Results are reported in parts per million dry weight.**

	Mean	Range	n
Aluminum	10.270	3.010 - 13.200	3
Copper	15.7	3.4 - 26.8	3
Lead	9.8	7.5 - 12.1	2
Mercury	0.040	0.011 - 0.068	3
Zinc	77.0	20.7 - 127	3

### **Fish Program**

Four fish species were collected at the sampling site: longnose sucker, northern pike, walleye and mountain whitefish. Analysis of fish muscle tissue found concentrations of organochlorines, PCBs and toxaphene below detection limits in all species; however, measurable concentrations of naphthalene and phenanthrene were found in all four fish species (Table 4). The highest concentrations were observed in longnose sucker tissue. A number of other PAHs were observed in longnose sucker tissue, but were below detection limits in tissue from the other species. Further work was initiated to understand the PAH in fish results. Benthic invertebrate sampling and analysis for PAHs was recommended to determine possible food sources of PAHs in fish. MFO analysis was included to determine if exposure of PAHs is causing fish stress. Although PAH concentrations were relatively low, further analysis is warranted.

**Table 4.**

**Mean concentrations of two PAHs in Liard River fish muscle tissue for samples collected in 1992. Results are reported in parts per billion dry weight with the range in parenthesis.**

	Naphthalene	Phenanthrene
Longnose Sucker (n=9)	2.524 (1.519-6.673)	1.300 (0.553-2.149)
Northern Pike (n=9)	1.049 (0.386-1.424)	0.365 (0.223-0.731)
Walleye (n=10)	1.417 (1.313-1.521)	0.450 (0.240-0.787)
Mountain Whitefish (n=7)	2.164 (1.731-2.641)	1.720 (0.724-3.130)

Preliminary plots of concentration of two PAHs against weight for longnose sucker and northern pike are shown in Figures 2a. and 2b. Although a decreasing concentration of naphthalene and phenanthrene with increasing weight is seen for both fish species, the small sample size precludes statistical analysis for trends. Data on metal concentrations in fish tissue are pending analysis.

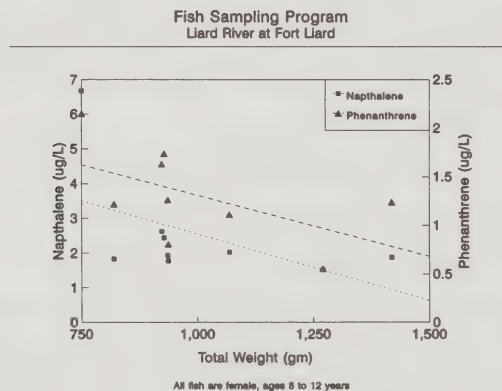


Figure 2a. Fish muscle tissue analysis, longnose sucker.

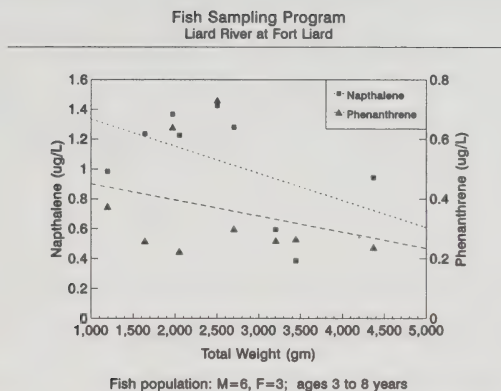


Figure 2b. Fish muscle tissue analysis, northern pike.

## FUTURE DIRECTIONS

The data collection program will continue for one more year. The program will then be reviewed and a decision made on future needs. Bathymetric information and water, sediment, benthic invertebrate and fish samples will be collected from Cormack Lake. These data will be used for comparison purposes.

## PUBLICATIONS AND REPORTS GENERATED

MacDonald Environmental Sciences Ltd. 1992. An Assessment of Ambient Environmental Conditions in the Liard River Basin, NWT. Report prepared under contract by MacDonald Environmental Sciences Ltd. for Water Resources Division, DIAND, Yellowknife.

Peddle, J. 1993. Liard River Monitoring Program, October 1993.



## **2.3 YELLOWKNIFE AND BACK BAYS ENVIRONMENTAL EVALUATION**

### **PROJECT COORDINATOR**

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Yellowknife, NWT

### **PROJECT OBJECTIVE**

To respond to concerns raised by in Ndilo and Dettah residents about water and fish quality. The project focussed on an environmental evaluation of Yellowknife and Back Bays of Great Slave Lake by conducting an extensive water, sediment and fish sampling program over two years.

### **DESCRIPTION**

The need for this study was identified in 1992 by Yellowknife Dene Bands in Ndilo and Dettah, who expressed concerned about water quality and trace metal contamination of fish in these two bays of Great Slave Lake. Specifically the bands were concerned about concentrations of arsenic in water, sediment and fish. The study was designed by the Yellowknife-Back Bay Working Group, a committee consisting of representatives from the Ndilo and Dettah bands, DIAND, Department of Fisheries and Oceans and the Government of the NWT Health. The study area is located in the north arm of Great Slave Lake (Figure 1). Site descriptions are given in Table 1.

Both the Yellowknife and Back Bays are used heavily by the City of Yellowknife and surrounding area. Back Bay receives effluent from the Royal Oak Mines Inc. gold mine through Baker Creek, and until November 1981, also received sewage effluent from Niven Lake. Back Bay is also used extensively by local residents for recreational purposes and has a small float plane airport. During the winter, the Bay is used extensively by snowmobiles. Yellowknife Bay also receives industrial effluent from the Miramar Con mine through the Meg-Peg-Keg lakes system. It is also used for recreational purposes such as fishing and swimming at the Dettah Community Dock.

# Yellowknife/Back Bay Study 1992-1994

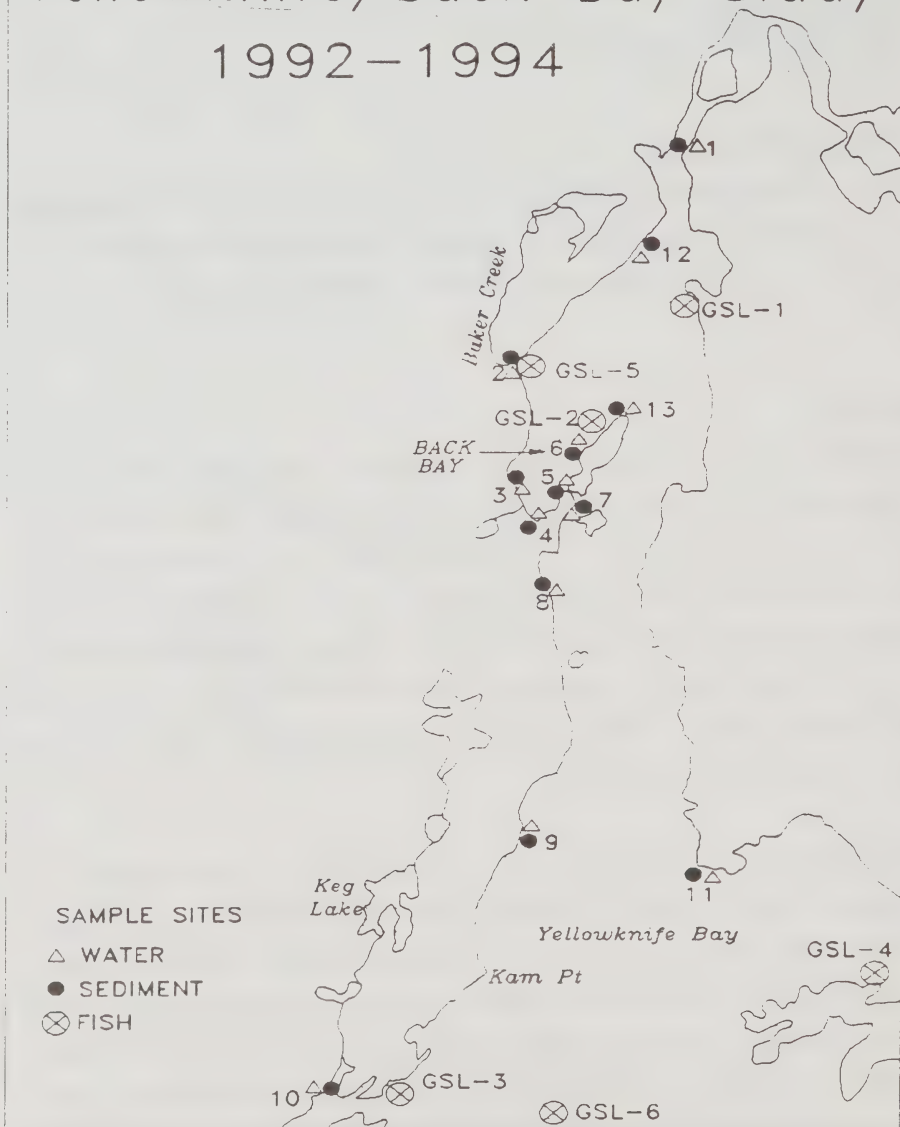


Figure 1 Sample Locations of the Yellowknife-Back Bay Study  
(North Arm of Great Slave Lake)

Although public concern focuses mainly on arsenic and mercury contamination, and coliform levels, a number of other trace metals were measured in water, sediment and fish samples. To help answer the question "Are the fish safe to eat?" Mackenzie Regional Health Services of the NWT Department of Health has conducted a long-term dietary study in this region. Their findings will be compared to the results of heavy metals in fish tissue from this study as part of a larger health risk assessment conducted by Health Canada, Ottawa. The findings of this comparison should be available in 1995.

**Table 1.**  
**Sample Sites for the Yellowknife-Back Bay Water and Sediment Study**

Site Number	Location
1.	upstream of bridge approximately 100m
2.	Baker Creek at Great Slave Lake (GSL)
3.	Niven Lake at GSL
4.	Peace River Flats in Back Bay
5.	left side of Causeway going to Latham Island
6.	Ndilo dock on the Back Bay side
7.	Joliffe Island between DFO dock and the Island
8.	Emergency Water Intake at GSL
9.	Meg release - near Negus Point at GSL
10.	Peg near mouth of GSL
11.	Dettah dock
12.	Giant Mine - old tailings release area tip of Latham Island

**Sampling Program:** Water and sediment samples were collected at the 13 sites in September 1992, February, June and August 1993, and February 1994 with the assistance of lay samplers from Dettah and Ndilo. For both years, fish were collected at six sites. Water

samples were analyzed for physical parameters, major ions, nutrients, trace metals and coliform bacteria. Sediment and fish were analyzed for trace metals including arsenic, cadmium, copper, mercury, nickel, selenium and zinc.

## PRELIMINARY RESULTS

**Water Quality:** Results from the water sampling program show clearly the influence of industrial activities in both bays (Tables 2a and 2b). In Back Bay, total arsenic concentrations are consistently low at the Yellowknife River sampling point (site 1) but increase markedly at the Baker Creek location (site 2). Highest levels reported are 247  $\mu\text{g/L}$  in June 1993 and 170 in August 1993. Both samples exceeded the Canadian Water Quality Guideline of 50  $\mu\text{g/L}$  for drinking water and protection of freshwater aquatic life. These values are related to the decant from the Royal Oak mine during the June to September period. The water licence limit for total arsenic for the Royal Oak mine is 500  $\mu\text{g/L}$ , thus all values are within the water licence limit. A summary of arsenic levels at the outlet of Baker Creek for 1994 is shown in Figure 2. The spatial extent of the mine decant can be seen in Yellowknife Bay samples collected during that period (sites 8 - 11). While results are below the Canadian Water Quality Guideline, they are significantly higher than other samples collected in this bay.

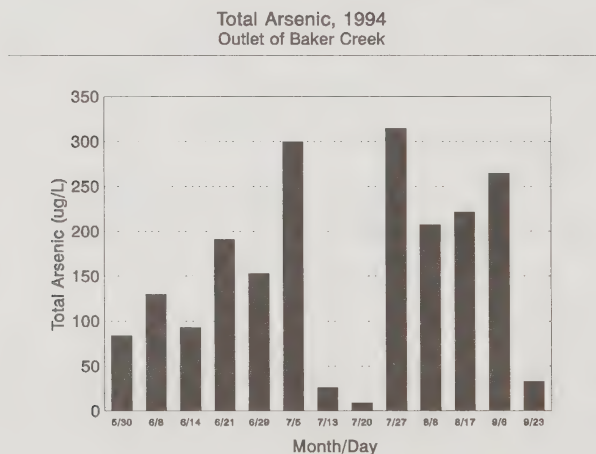


Figure 2. Total Arsenic Concentrations at the Outlet of Baker Creek, 1994

**Table 2a.**  
**Total Arsenic Results in  $\mu\text{g/L}$  from Back Bay Samples**

	Sampling Location			
Sampling Date	1	2	12	13
Sept. 1992	0.3	5.7	2.9	0.5
Mar. 1993	0.3	0.4	0.3	0.4
June 1993	0.3	247.0	7.8	3.3
Aug. 1993	0.3	170.0	0.3	6.7
Jan.-Feb. 1994	L0.3	0.9	L0.3	0.3
Mar. 1994	L0.3	L0.3	0.3	0.4

**Table 2b.**  
**Total Arsenic Results in  $\mu\text{g/L}$  from Yellowknife Bay samples.**

	Sampling Location			
Sampling Date	8	9	10	11
Sept. 1992	4.6	3.4	31.0	1.3
Mar. 1993	1.3	0.8	7.5	1.0
June 1993	2.9	1.4	34.8	1.1
Aug. 1993	4.2	0.6	38.6	0.7
Feb. 1994	0.7	0.6	20.8	0.4
Mar. 1994	0.6	0.6	5.6	0.4

Mercury, the other trace element of concern, reports consistently at or below the detection limit of 0.04 µg/L for samples collected in 1992 and a detection limit of 0.02 µg/L in all other samples.

Results of water analysis for the September 1992 samples indicate that bacteria as total and faecal coliform exceeded the Canadian Drinking Water Quality Guideline of 10 total coliform/100mL in 10 of the 13 sites and 0 faecal coliform/100ml in three of the 13 sites. Because of these findings, Health Canada officials had to remind the public that if raw water was going to be used as a source of drinking water, it must be properly chlorinated or boiled prior to consumption. All water samples were well below the recreational water quality guideline of 200 total coliform/100 mL sample.

A temporal trend in total ammonia nitrogen can be seen for the five samples collected at site 10, the outlet of Peg Lake at Great Slave Lake (Figure 3). During the summer months concentrations exceed the Water Quality Guideline of 2.2 mg/L at near neutral pH and temperatures of 10 - 15°C. A specific reason for these elevated levels cannot be determined, but possible sources are extensive use of nitrogen-ammonia based explosives at the mine, the discharge of raw sewage from Miramar-Con housing facilities to the tailings pond for treatment or the natural release of nitrogen from wetlands that drain to the Meg-Keg-Peg Lake system.

Based on the Mackenzie Regional Health Services health risk assessment, it was concluded that the water was safe to drink, provided it was treated either chemically or by boiling, and safe for swimming.

**Sediment Analyses:** The only significant finding from the analyses of sediments from three sampling periods are the elevated levels of arsenic at site 2, the outlet of Baker Creek at site 10, the outlet of Peg Lake at Great Slave Lake (Table 3). Because arsenopyrite is found in gold ores in this area, these elevated levels are not considered unusual.

**Ammonia-nitrogen**  
**Outlet of Peg Lake at Great Slave Lake**

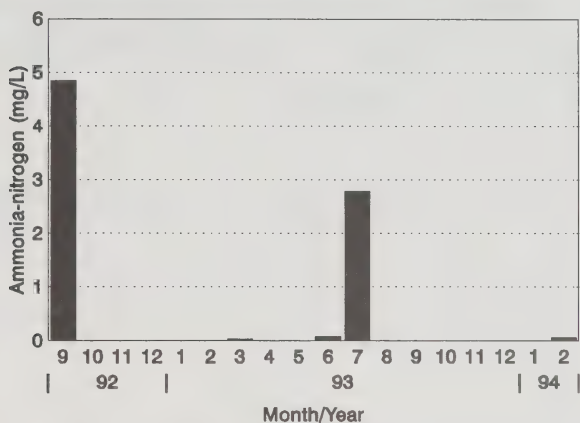


Figure 3. Ammonia-nitrogen Concentrations of Five Samples Collected at Outlet of Peg Lake at Great Slave Lake

**Table 3.**

**Summary of concentrations in  $\mu\text{g/g}$  Dry Weight of Select Trace Elements in Sediments for Three Samples at Two Sites**

Trace Element	Outlet of Baker Creek		Outlet of Peg Lake	
	Mean	Range	Mean	Range
Arsenic	1820	1335 - 2550	223.3	125 - 393
Cadmium	0.723	0.655 - 0.836	0.570	0.47 - 0.73
Copper	428	412.5 - 534.0	51.1	39.83 - 69.6
Mercury	0.120	0.100 - 0.136	0.024	0.47 - 0.5
Zinc	302.9	274 - 342	97.6	73.9 - 111

**Contaminants in Fish Tissue:** Over 400 lake whitefish, walleye, longnose sucker, burbot and northern pike were collected from the two bays in 1992 and 1993. The fish muscle, liver and kidney were analyzed for arsenic, cadmium, copper, lead, mercury, nickel, selenium and zinc. Because of its environmental and health significance, a summary of mercury in fish tissue is shown in Table 4. Results of the fish sampling are presently being reviewed by Health Canada and are pending.

**Table 4.**  
**Summary of Mercury in Fish Tissue in  $\mu\text{g/g}$  Dry Weight for Five Fish Species**

	Mean	Range	n
lake whitefish	0.060	0.017 - 0.224	195
walleye	0.149	0.073 - 0.240	30
longnose sucker	0.042	0.021 - 0.100	30
burbot	0.151	0.058 - 0.390	73
northern pike	0.200	0.076 - 0.470	109

## FUTURE DIRECTIONS

Additional sampling and analysis is required to further develop trends identified in the preliminary analysis of data. Upon completion of this study and the Health Canada health risk assessment, the Water Resources Division will meet with the chiefs of Ndilo and Dettah to present the findings. Further community consultations are anticipated.

## **2.4 CENTRAL ARCTIC STUDY**

### **PROJECT COORDINATOR**

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Water Resources Division  
Indian and Northern Affairs Canada  
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### **CONSULTANTS**

S. Bunge, Private Consultant  
3505 Ingraham Drive  
Yellowknife, NWT

AGRA Earth and Environmental Limited  
221-18th Street S.E.  
Calgary, AB

### **PROJECT OBJECTIVE**

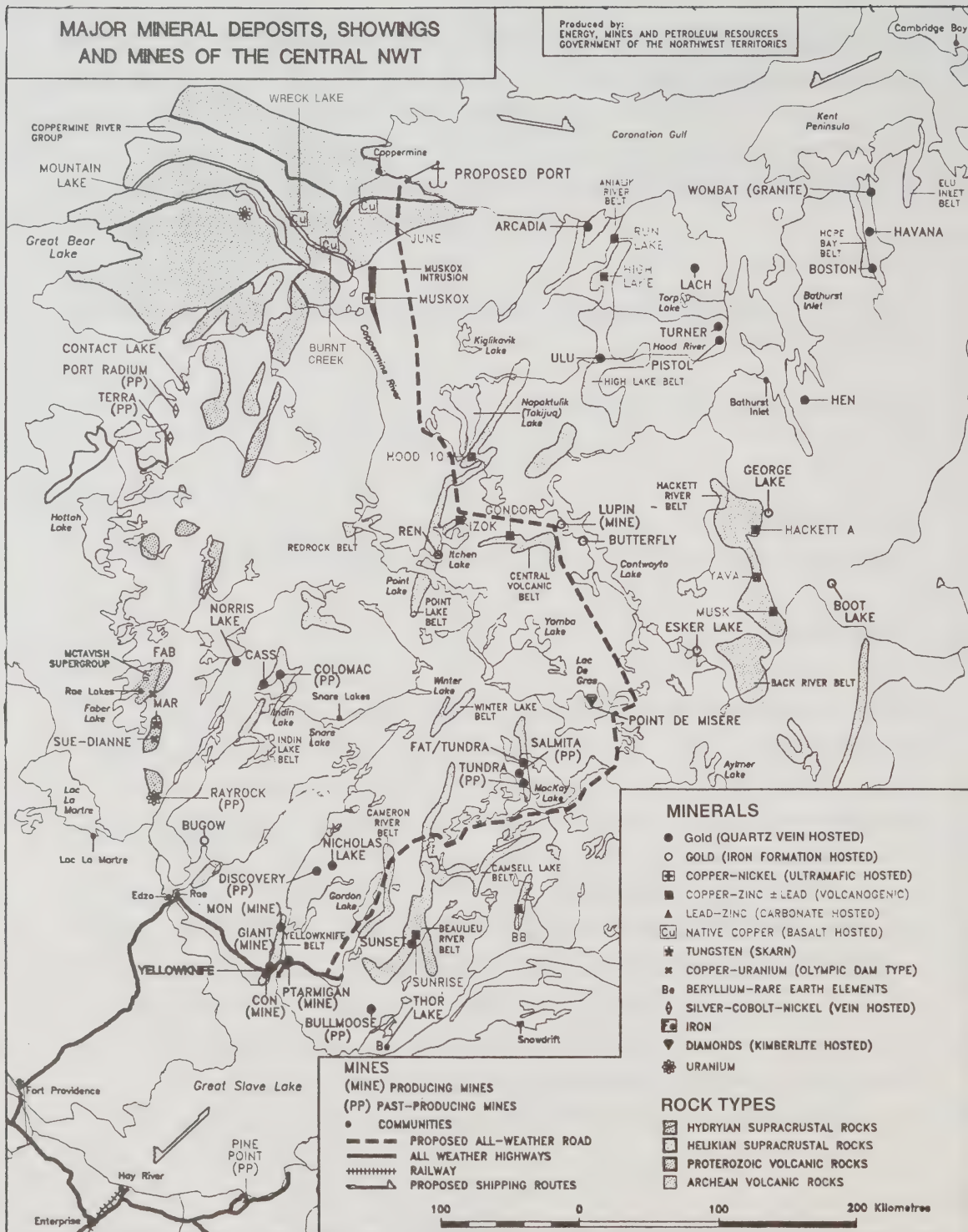
To determine baseline water and sediment quality of lakes in the Slave Province area.

### **DESCRIPTION**

Northern Canada is divided into nine distinct geological subdivisions termed structural provinces, each having distinct structural style and orogenic history. The oldest structural province is the Slave, which is located north of Great Slave Lake and extends north to the Arctic Ocean. The Slave Province is bounded on the west by the Bear Province and to the east by the Churchill Province. Rocks of Archean and Aphebian age, containing numerous gold and volcanic base metal deposits, make the area very attractive to the mining industry. Recently, exploration activities have increased and a number of diamond discoveries have been made. It appears that one or more sites may be developed. Figure 1 illustrates the extent of the proposed development activities in the Slave Province. Developments are proposed at several sites, including Izok Lake and Lac de Gras. Because mining developments also invite other types of industry and activities such as exploration camps, hydroelectric power and winter roads, all these activities have the potential to negatively impact the surrounding area.

Water quality information on the Slave Province is sparse and limited. The few studies done

Figure 1



were a result of impact assessments for individual developments. Because of active exploration and potential development activities, there is an increasing need for accurate water quality information.

In response to these proposed activities, the Central Arctic Study was initiated. The study focuses on the area between the north shore of Great Slave Lake and the south shore of Coronation Gulf and between Camsell River and Artillery Lake. The baseline nature of the sampling program dictated a general approach to the selection of parameters. Parameters measured in the field included temperature, pH, conductivity and depth. Laboratory measurements included turbidity, suspended solids, alkalinity and several trace elements in water and sediment samples. Because water and sediment quality vary in time and in space, this study focused on the spatial variability of water and sediment quality parameters.

#### **ACTIVITIES IN 1994**

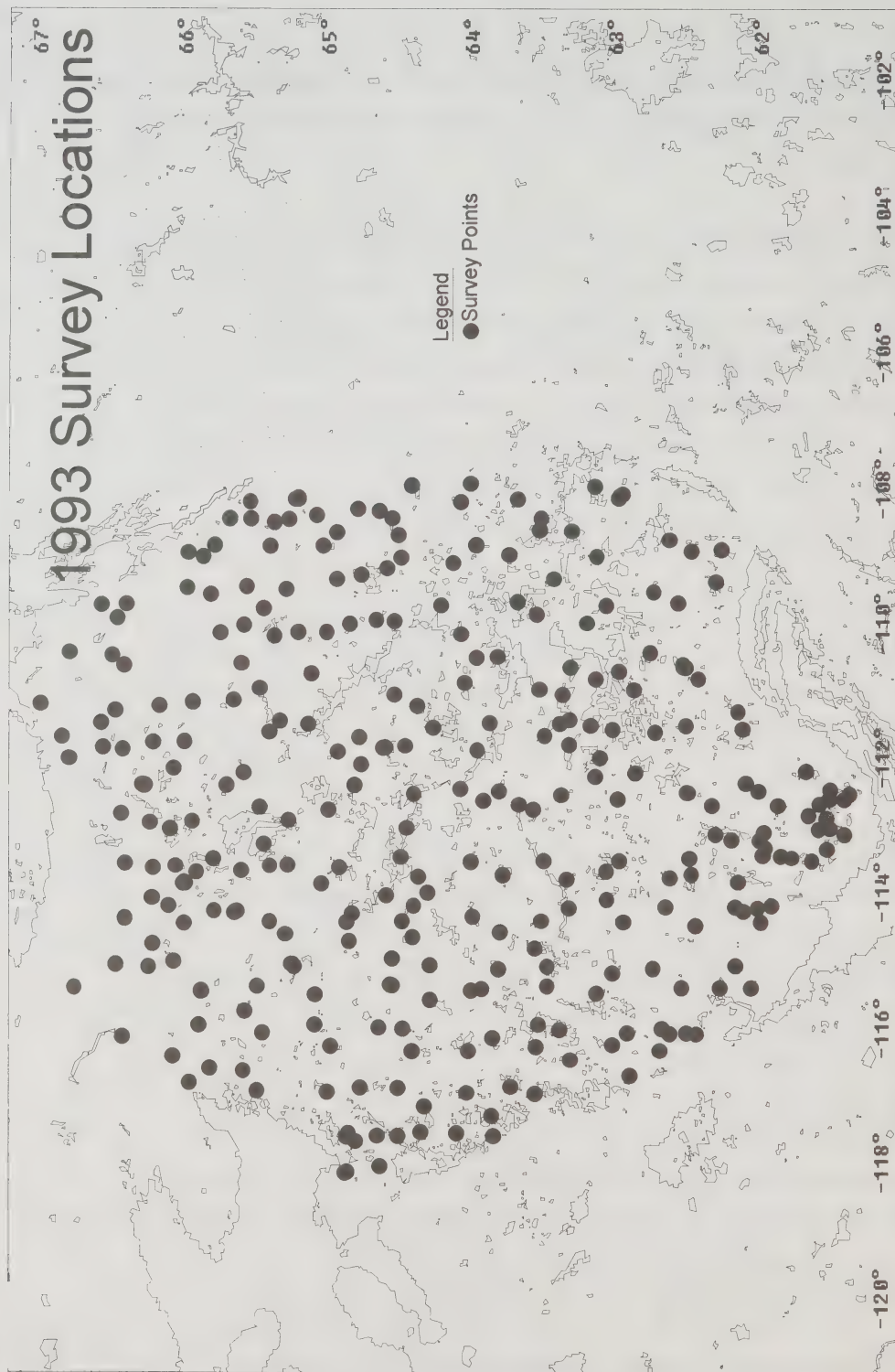
AGRA Consultants were contracted in 1993 to collect and summarize water quality and hydrological data for the Slave Province; identify past, present, and future developments that may affect water quality; and design a sampling program to measure the current lake water and sediment quality.

Sara Bunge, a private consultant, was also contracted to collect water and sediment samples in the study area during the open water season. Lake water and bottom sediment samples were collected throughout the study area from a float plane. Lakes were selected randomly based on a 25 km grid and at known development sites. Water samples were collected with a 3 litre Van Dorn sampler and sediment samples with an Ekman dredge. In total, samples were collected from 296 lakes (Figure 2).

#### **FUTURE DIRECTIONS**

The raw data will be incorporated into a database for the study area and geographical information system techniques will be used to display and analyze data. The mapping of the data

Figure 1



will identify spatial trends in water and sediment quality. The software to be used for this analysis is SPANS GIS.

The Central Arctic Study will provide DIAND with valuable water and sediment quality information on an area where information is sparse. The study may also provide information to support future studies and will enable the assessment of potential changes because of current and potential development.

Lakes missed due to unfavourable weather will be sampled in the next fiscal year. Areas where data anomalies are observed will be investigated further.

Part of the sediment samples may be analyzed by Geological Survey of Canada for minerals and trace elements.

## **PUBLICATIONS AND REPORTS GENERATED**

HBT AGRA Limited. Oct 1993. Water Quality in the Slave Structural Province. 86p.

Puznicki W. 1993 An Overview of Lake Water and Bottom Sediment Quality in the Slave Province Area, Poster, 21<sup>st</sup> Annual Geoscience Forum. Yellowknife, NWT. December 1-3, 1993. 5p.



## **2.5 BIOMAGNIFICATION OF PERSISTENT ORGANIC CONTAMINANTS IN GREAT SLAVE LAKE<sup>1</sup>**

### **PROJECT COORDINATOR**

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National Hydrology Research Institute  
Environment Canada  
Saskatoon, SK

### **PROJECT TEAM**

D. Muir and W.L. Lockhart  
Freshwater Institute  
Winnipeg, MA

### **PROJECT OBJECTIVES**

#### **Long-term:**

1. To determine the concentrations of persistent organic contaminants in various components of Great Slave Lake food webs;
2. To determine the influence of the Slave River on the contaminant loading to Great Slave Lake; and
3. To determine the influence of the Slave River on the biomagnification of persistent organic contaminants in Great Slave Lake food webs.

#### **Short-term:**

1. To determine organic contaminant concentrations in whitefish, burbot, and lake trout collected from two regions of Great Slave Lake, i.e., an area strongly influenced by the Slave River and a second, more isolated "control" area. Compare these data with data collected from other subarctic and arctic regions; and

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<sup>1</sup>Editors' Note: This project is also funded under the AES Northern Contaminants Program. This summary also appears in Environmental Studies No. 72. Synopsis of Research Conducted under the Northern Contaminants Program. The Action on Water Program funded the March 1992 collection of water and sediment, the August 1993 surficial and core sediment sampling and the March 1994 collection of sediment.

2. To conduct preliminary collections of plankton, mysids, and amphipods in the West Basin of Great Slave Lake (i.e., near the Slave River outflow) to determine abundance patterns and to investigate methods for obtaining large numbers of organisms required for organic contaminant determinations (1994-95).

## **DESCRIPTION**

This project is investigating pathways (atmospheric, riverine) by which persistent organic contaminants are transported to and biomagnified in Great Slave Lake food webs. It also is investigating the potential implications of increased development in the Great Slave Lake drainage basin on contaminant loading to the lake. Such implications include an increase in contaminant body burdens in fish with potential economic consequences to the sport and commercial fisheries and to the well-being of people who consume these fish. Ultimately, down-river transport via the Mackenzie River may result in increased contaminant loading to the Arctic Ocean.

## **ACTIVITIES IN 1994**

Two regions were selected for investigating the influence of the Slave River on contaminant loading and biomagnification in Great Slave Lake fish. Resolution Bay, near the Slave River delta in the West Basin, was selected as the general location for investigating organic contaminant concentrations in fish in a region strongly affected by the Slave River. Lutsel K'e (Snowdrift), in the East Arm, was selected as a "control" site for a region under relatively weak Slave River influence.

The communities at Fort Resolution (Slave River delta) and Lutsel K'e were informed of the objectives of the study and their assistance was requested in collecting burbot, whitefish, and lake trout. Fifteen lake trout, twenty whitefish, and five burbot were collected from the vicinity of Lutsel K'e in early autumn. Eleven whitefish and nine burbot were collected from Resolution Bay in December. In January 1994, nine lake trout were provided by commercial fishermen (from Hay River) operating in the western West Basin. Lake trout, burbot, and whitefish then were analyzed for persistent organochlorine contaminant concentrations including toxaphene and

PCB congeners. Pooled samples were analyzed for PAHs, dioxin and furans. Fish also were aged, weighed, and their sex and length determined.

In August 1993, a four-day research cruise was conducted in the Slave River delta region using the enforcement vessel operated by Fisheries and Oceans, Hay River. Information was obtained on the spatial patterns of plankton, mysid, and amphipod distribution in the vicinity of the Slave River plume. The cruise also allowed for the determination of potential difficulties which might be encountered in collecting the large numbers of invertebrates required for organic contaminant analysis in 1994-95. Limited sampling was conducted of the water column, i.e., temperature, conductivity, turbidity, and plant nutrients.

A series of 10 surficial sediment samples were collected during the four-day cruise. Samples were collected along two, four-station transects west and immediately offshore of the Slave River outflow and one, two-station transect east of the River mouth. These samples were then analyzed for concentrations of persistent organochlorine contaminants (including PCBs and toxaphene), PAHs, dioxins and furans. In addition, two short cores were collected in a shelf region offshore of Resolution Bay. These cores were collected for dating determinations to ascertain whether or not this region of the delta is suitable for historic contaminant deposition studies (i.e., core studies).

In February 1994, funding (55 K) was received from the Northern River Basin Study (NRBS) to collect a series of sediment core samples in the West Basin of Great Slave Lake. This field sampling was conducted by M. S. Evans and R. Bourbonniere (National Water Research Institute).

## **RESULTS**

The analyses of lake trout, burbot, and whitefish collected in 1993-94 are near completion. A brief summary of the results to date is presented in the following paragraphs. Statistical analyses of the data (for differences in contaminant concentration between species and region) will begin following the completion of all chemical analyses.

Whitefish from Resolution Bay tended to be younger and have a higher lipid content than whitefish from Lutsel K'e. Toxaphene was the predominant organochlorine detected in whitefish muscle followed by total PCBs and chlordane (Table 1). Data were highly variable and differences in contaminant concentrations between sites, if statistically real, were small.

Lake trout from the West Basin had a higher lipid content than lake trout from Lutsel K'e (Table 1). Toxaphene was the predominant organochlorine contaminant detected. There was some evidence that West Basin trout had lower toxaphene concentrations than trout from the East Arm. PCB, DDT, and chlordane concentrations also appeared lower in West Basin than Lutsel K'e lake trout. Statistical analyses will be used to test this hypothesis.

Burbot analyses have not been completed. Limited data suggest that toxaphene, PCB, DDT, and chlordane concentrations may be lower in West Basin than in Lutsel K'e burbot liver (Table 1).

Two pools each of the three fish species from the West Basin and East Arm were analyzed for dioxins and furans. Low concentrations (1.00 pg/g) of dichlorodibenzodioxin were detected in burbot liver from Resolution Bay. Whitefish and lake trout muscle from Resolution Bay contained 0.05 and 0.15 pg/g of tetrachlorodibenzodioxin, respectively. The only dioxin detected in fish from Lutsel K'e was hexachlorodibenzodioxin (0.55 pg/g) in burbot liver.

Furans were more readily detected in fish from the West Basin and East Arm. For the West Basin, low concentrations of tetrachlorodibenzofuran were detected in burbot liver (2.65 pg/g), whitefish muscle (0.70 pg/g) and lake trout muscle (0.75 pg/g). Trichlorodibenzofuran (0.05 pg/g) was detected in lake trout muscle and pentachlorodibenzofuran was detected in whitefish (0.15 pg/g) and lake trout (0.10 pg/g) muscle. For the East Arm, tetrachlorodibenzofuran was detected in burbot liver (11.75 pg/g), whitefish muscle (0.55 pg/g), and lake trout muscle (0.55 pg/g). Pentachlorodibenzofuran was detected only in burbot liver (0.80 pg/g) and lake trout muscle (0.10 pg/g).

PAH concentrations were low in burbot liver (2.44 ng/g), whitefish muscle (2.65 ng/g) and lake trout muscle (2.39 ng/g) from Lutsel K'e. Naphthalene, 2-methylnaphthalene, and 1-methylnaphthalene were the primary compounds detected. Fish from the West Basin have yet to be analyzed.

The lake survey provided interesting information on the limnology and aquatic ecology of Great Slave Lake in the vicinity of the Slave River plume. Turbidity decreased markedly with depth suggesting that, during summer stratification, river-borne contaminants are dispersed into the West Basin with the surface river plume. Moreover, some of these river-borne contaminants may be transported with Great Slave Lake outflow via the Mackenzie River. Nutrient data showed evidence that the Slave River is an enriched source of particulate organic carbon, nitrogen and phosphorus to the West Basin of Great Slave Lake. Ultimately this enrichment may affect the lipid content of fish and their contaminant body burdens.

Zooplankton densities were low but the samples relatively free of large, organic debris. Mysids were relatively abundant and readily caught even during daylight hours. Amphipods (benthos), occurring in low densities and in "sticky" sediments, were the most difficult to sample. Amphipods were small in comparison to amphipods from Lake Michigan and Ontario.

Analyses of sediment samples (funded by Indian and Northern Affairs Canada in Yellowknife) are continuing. The March 1994 coring trip (supported by NRBS) was successful with a good to excellent series of cores collected at five sites in the West Basin. Following the dating of these cores, a series of core sections will be selected for organic contaminant analysis with 1994-95 AES funding.

## **DISCUSSION AND CONCLUSIONS**

Initial results of our study indicate that most organochlorine contaminants occur in relatively low concentrations in whitefish, lake trout, and burbot collected from the two regions of Great Slave Lake. Similarly, regional differences in organic contaminant concentrations in fish collected from the two regions are generally small. Notable exceptions are: toxaphene in lake trout,

Table 1. Mean (and standard deviation) concentration of organochlorine contaminants in whitefish muscle, lake trout muscle, and burbot liver from Resolution Bay (Hay River for lake trout) in the West Basin and Lutsel K'e in the East Arm of Great Slave Lake. Concentrations are ng/g wet weight.

Parameter	Whitefish		Lake trout		Burbot	
	Lutsel K'e	Resolut.	Lutsel K'e	Resolut.	Lutsel K'e	Resolut.
Age - M	14.3 ± 4.2	11.4 ± 1.8	13.0 ± 4.1	-	16+	13+
Age - F	17.5 ± 2.1	11.5 ± 5.0	16.0 ± 6.7	-	11.8 ± 2.8	-
%Lipid - M	2.5 ± 1.3	6.7 ± 1.6	7.4 ± 3.7	11.2 ± 1.2	20.9	19.5
%Lipid - F	3.1 ± 1.4	4.4 ± 0.7	7.9 ± 4.7	13.8 ± 3.6	32.3 ± 6.9	-
s-CBZ M	1.2 ± 0.7	2.4 ± 1.4	3.1 ± 1.3	2.4 ± 1.0	23.1	13.2
s-CBZ F	1.6 ± 0.6	1.2 ± 0.4	3.3 ± 3.0	2.7 ± 0.9	14.8 ± 2.4	-
s-HCH M	0.8 ± 0.7	1.8 ± 0.4	2.6 ± 1.2	1.8 ± 0.8	15.2	7.3
s-HCH F	0.9 ± 0.4	1.4 ± 0.2	2.6 ± 1.7	2.1 ± 0.6	9.7 ± 5.3	-
s-CHLOR M	4.2 ± 2.6	6.2 ± 4.8	16.1 ± 7.8	9.2 ± 5.9	152.4	76.9
s-CHLOR F	5.1 ± 2.5	3.1 ± 1.6	17.4 ± 13.0	10.7 ± 4.6	78.7 ± 12.7	-
s-DDT M	2.1 ± 1.3	1.7 ± 1.3	9.7 ± 4.8	5.3 ± 4.4	95.7	27.8
s-DDT F	2.1 ± 0.9	1.0 ± 0.7	9.5 ± 9.8	6.1 ± 3.1	40.1 ± 7.7	-
s-PCB M	5.9 ± 3.9	5.2 ± 5.6	23.1 ± 10.1	13.1 ± 9.9	227.5	92.5
s-PCB F	5.1 ± 5.1	1.7 ± 1.2	26.8 ± 26.3	14.3 ± 6.4	116 ± 18	-
s-TOX M	29.3 ± 20.2	27.0 ± 22.7	140.7 ± 69	41.3 ± 24.1	1266.6	401.3
s-TOX F	38.7 ± 16.8	14.7 ± 8.7	160 ± 140	52.8 ± 24.7	635 ± 110	-
DIELD. M	0.5 ± 0.3	0.9 ± 0.3	1.0 ± 0.4	0.7 ± 0.3	15.8	7.2
DIELD. F	0.7 ± 0.4	0.6 ± 0.1	1.2 ± 0.8	0.8 ± 0.3	8.1 ± 2.2	-

burbot, and whitefish females; PCB in lake trout and burbot; DDT in burbot; and HCH in burbot. Statistical analyses (nonparametric tests) will be performed to determine whether or not such differences are significant.

There were interesting similarities and differences in organochlorine contaminant concentrations in Great Slave Lake and Lake Laberge fish (Muir and Lockhart 1993). Chlorobenzene, chlordane, HCH, and dieldrin concentrations were similar in Great Slave Lake whitefish to levels observed in Lake Laberge whitefish. However, toxaphene concentrations were slightly lower and DDT and PCB concentrations substantially lower in Great Slave Lake than Lake Laberge whitefish. Great Slave Lake lake trout contained lower concentrations of chlordane, DDT, PCB, and toxaphene than Lake Laberge lake trout. Great Slave Lake burbot also contained lower concentrations of DDT and PCB than burbot of Lake Laberge. Toxaphene values were similar for Lake Laberge and Lustel K'e lake trout but higher than lake trout collected from the West Basin. Whitefish, lake trout, and burbot from Great Slave Lake had similar lipid concentrations as the same species from Lake Laberge. Therefore, differences in organic contaminant concentrations in fish inhabiting the two lakes may be related to factors such as fish age, feeding behaviour, and/or genetic differences in their ability to metabolize xenobiotic compounds.

PAH, dioxin, and furan concentrations were relatively low in burbot, whitefish, and lake trout collected from the two regions of Great Slave Lake. Regional differences were subtle. Analysis of surficial sediment samples collected in August 1993 will provide a strong basis for evaluating the influence of the Slave River on contaminant loading to Great Slave Lake. With this information, and the completion of analyses of fish collected in 1993-94, we will continue to investigate regional differences in organic contaminant concentrations in fish tissue. Research in 1994-95 will focus on the further elucidation of these questions.

**Expected project completion date:** March 1997

## REFERENCE

- Muir, D. and W.L. Lockhart. 1993. Food chain accumulation and biological effects of organochlorines in fish from Lake Laberge and other Yukon lakes. Pp. 167-173 *in*: Synopsis of Research Conducted Under the 1992/93 Northern Contaminants Program, J.L. Murray and R.G. Shearer (eds.). Environmental Studies No. 70. Indian and Northern Affairs Canada, Ottawa. 285 pp.

## **2.6 WAGER BAY BASIN OVERVIEW**

### **PROJECT TEAM**

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### **PROJECT OBJECTIVES**

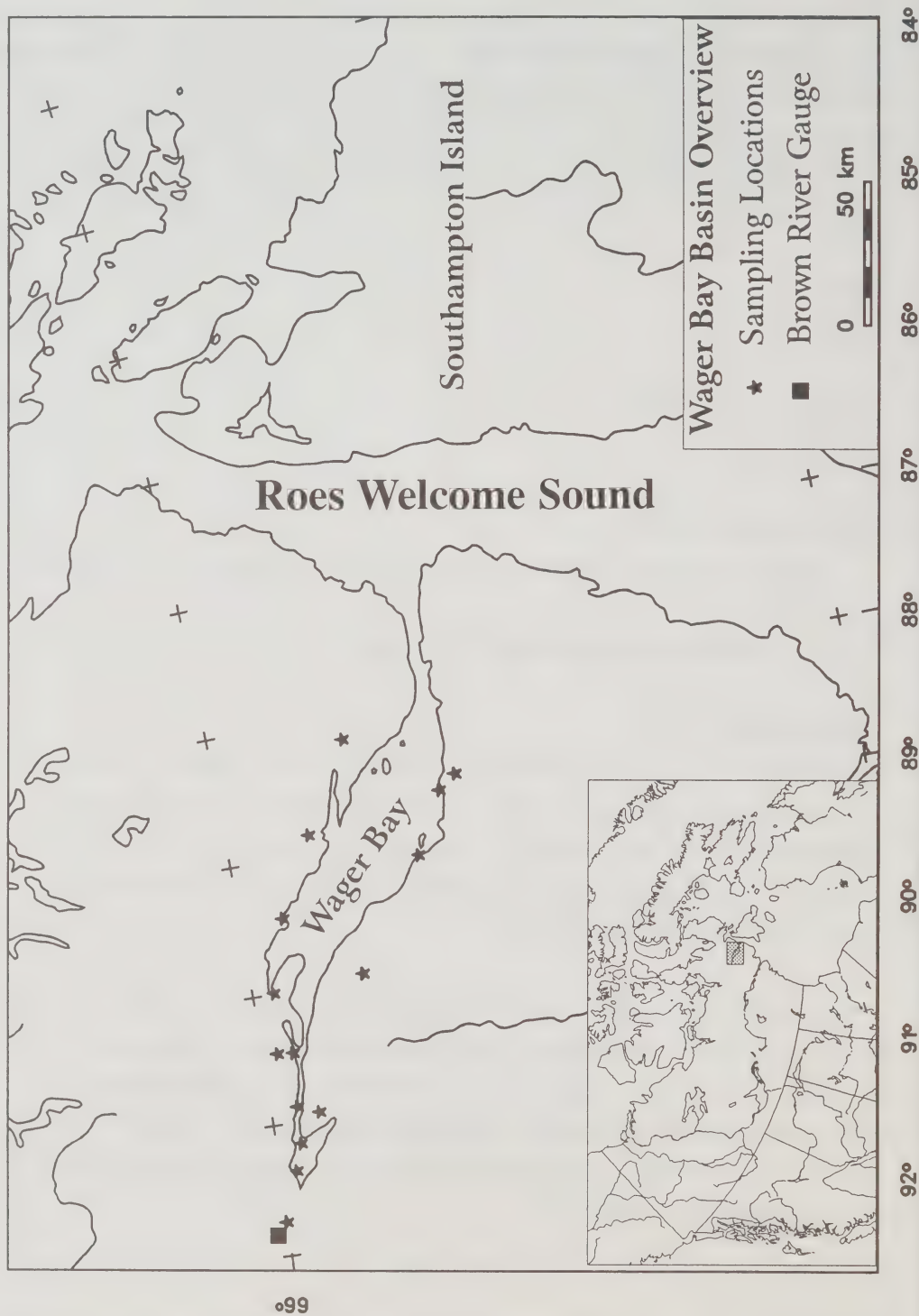
1. To collect baseline water quality and water quantity data in the Wager Bay drainage basin; and
2. To characterize the geomorphology of the selected streams during site visits.

### **DESCRIPTION**

Wager Bay Basin, located in the northeastern District of Keewatin, consists of a relatively large inlet flowing into the Northwestern portion of Hudson Bay (Figure 1). There are no major settlements within the Wager Bay Basin. This area has been infrequently studied, with little hydrologic and water quality information available. The nearest major settlements are Baker Lake, Coral Harbour and Repulse Bay.

Since early 1993, Environment Canada, DIAND and Canadian Heritage have shared a common interest in characterizing the water and other resources in the Basin and in preparing a basin overview. There are many potential land uses in the basin including mineral and petroleum development, hydro power development, hunting and fishing, recreation, and environmental conservation and protection. The Basin is located in an area proposed for national park status and is also within the Nunavut Territory.

Figure 1



To characterize the baseline conditions of the basin, a cooperative study among Heritage Canada, Environment Canada and DIAND was planned. This basin overview is the fifth in a series and will characterize the Northern Arctic Ecozone. Other overviews have been done of the Hay, Coppermine, Yellowknife and the South Nahanni rivers. A sixth and final overview is planned for the Baffin/Ellesmere Island area. The program involves measuring stream flow and sampling for baseline water quality at several rivers flowing into Wager Bay within the proposed Wager Bay National Park Reserve area. Water and sediment samples were also collected from several nearby lakes to assess water and sediment chemistry.

### **ACTIVITIES IN 1993-94**

Stream flow measurements were taken at six sites and geomorphological characteristics were recorded for 10 stream sites. Water quality and sediment samples were taken at four lake sites and six stream sites. Spring break up flow characteristics were monitored in May and June 1994. Further water quality sampling was also done at this time.

The hydrometric site on the Brown River was identified by the Atmospheric Environment Services of Environment Canada as an optimal location for installing meteorological equipment to the existing satellite transmission Data Collection Platform.

### **FUTURE DIRECTIONS**

Results of water and sediment quality analysis are pending. Environment Canada meteorology equipment will be maintained indefinitely at the Brown River site and water quality sampling will continue at Brown River hydrometric site for several years.



## **2.7 NWT HYDROMETRIC STATION REGIONAL - HYDROLOGY ANALYSIS: YEAR 2**

### **PROJECT COORDINATOR**

B. Reid  
Water Resources Division  
Indian and Northern Affairs Canada  
Yellowknife, NWT

### **CONSULTANT**

Northwind Consultants (J.H. Wedel, R.L. Wedel and L.M. Wedel)  
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### **PROJECT OBJECTIVES**

1. To identify areas of hydrologic similarities using correlative statistical methods; and
2. To evaluate the hydrometric network in the NWT to identify station deficiencies and redundancies.

### **DESCRIPTION**

This contract consisted of Phase II of the NWT hydrometric network evaluation. In Phase I, the network was evaluated on a station-by-station basis. Results of this work can be found in INAC Network Evaluation: the Water Resources Management Perspective.

The current work, or Phase II of the hydrometric evaluation, expands on the station-by-station network evaluation to identify the areas where new stations should be established and to identify areas where data collection is adequate.

The study began with a comprehensive review of the historical hydrologic studies conducted in the NWT. Using the existing hydrologic data set for NWT and considering major derived parameters from the data (such as maximum and mean flows in various seasons), significantly

correlated stations were identified. This identification was possible with the use of statistical techniques such as factor analysis, linkage analysis and Pearson's correlation matrices. Data sets that grouped together hydrologically similar areas were established. Using this information, redundant stations were identified and areas where new stations are necessary.

## RESULTS

Results identified a priority list of 44 hydrometric stations for mainland NWT (Table 1).

The study also identified gaps in the regional hydrology profile and recommended the following additions:

1. 2 to 3 sites along the southern Hudson Bay Coast;
2. 3 to 4 sites in the upper Thelon, Dubawnt and Kazan Rivers;
3. 2 sites in the Wager Bay/Melville Peninsula region;
4. 2 sites in the Garry Lake region;
5. 3 sites in the Anderson River/Amundson Gulf region; and
6. 3 sites in Carnwath/mid-lower Mackenzie Valley region.

This knowledge has been used to assist in planning the expansion of the hydrometric network under the AES.

The study also produced two isoline maps that may be of use to water resources managers and northern development companies. Figure 1 consists of an isoline map of mean summer runoff rates ( $l/s/km^2$ ). Figure 2 consists of an isoline map of historic maximum floods ( $l/s/km^2$ ) for the NWT mainland. These maps can be used to estimate flow characteristics on ungauged catchments.

**TABLE 1. Priority Hydrometric Stations.**

Station Number		Group No.	Station Name		No Ice Effect
06EB003		0	Barrington River above First Rapids	MB	
07RD001	*	0	Lockhart River at outlet of Artillery Lake	NT	*
07TA001	*	0	La Martre River below outlet of Lac La Martre	NT	
10JA002	*	0	Camsell River at outlet of Clut Lake	NT	*
06KC003	*	0	Dubawnt River at outlet of Marjorie Lake	NT	
07LD003		0	Pipestone River below Rotariu Lake	SK	
10ED003		1	Birch River at Highway 7	NT	
10FB005	*	1	Jean-Marie River at Highway 1	NT	
10GC002		1	Harris River near the Mouth	NT	
10GC003	P	1	Martin River at Highway 1	NT	
07OA001		2	Sousa Creek near High Level	AB	
07OB004		2	Steen River	AB	
07OB006		2	Lutose Creek near Steen River	AB	
10ED006	*	2	Rabbit Creek at Highway 7	NT	
10JD002		3	Whitefish River near the mouth	NT	
10NA001	*	3	Carnwath River below Andrew River	NT	
10LA004		4	Weldon Creek near the Mouth	NT	
10LC003		4	Rengleng River below Highway 8	NT	
10LC007		4	Caribou Creek above Highway 8	NT	
10LC010	*	4	Boot Creek near Inuvik	NT	
10MD002		4	Babbage River below Caribou Creek	YT	
10NC001		4	Anderson River below Carnwath River	NT	
10NC002		4	Trail Valley Creek near Inuvik	NT	
06HD001	*	5	Kognak River below Mountain Lake	NT	
07RC001		5	Thonokied River near the mouth	NT	
10EB001	*	5	South Nahanni River above Virginia Falls	NT	
10EB002		5	Mac Creek near the mouth	NT	
10EB003		5	Lened Creek above Little Nahanni River	NT	
10HA003		5	Twitya River near the mouth	NT	
10KB001		5	Carcajou River below Imperial River	NT	
10KC001		5	Mountain River below Cambrian Creek	NT	
10LA002	*	5	Arctic Red River near the mouth	NT	

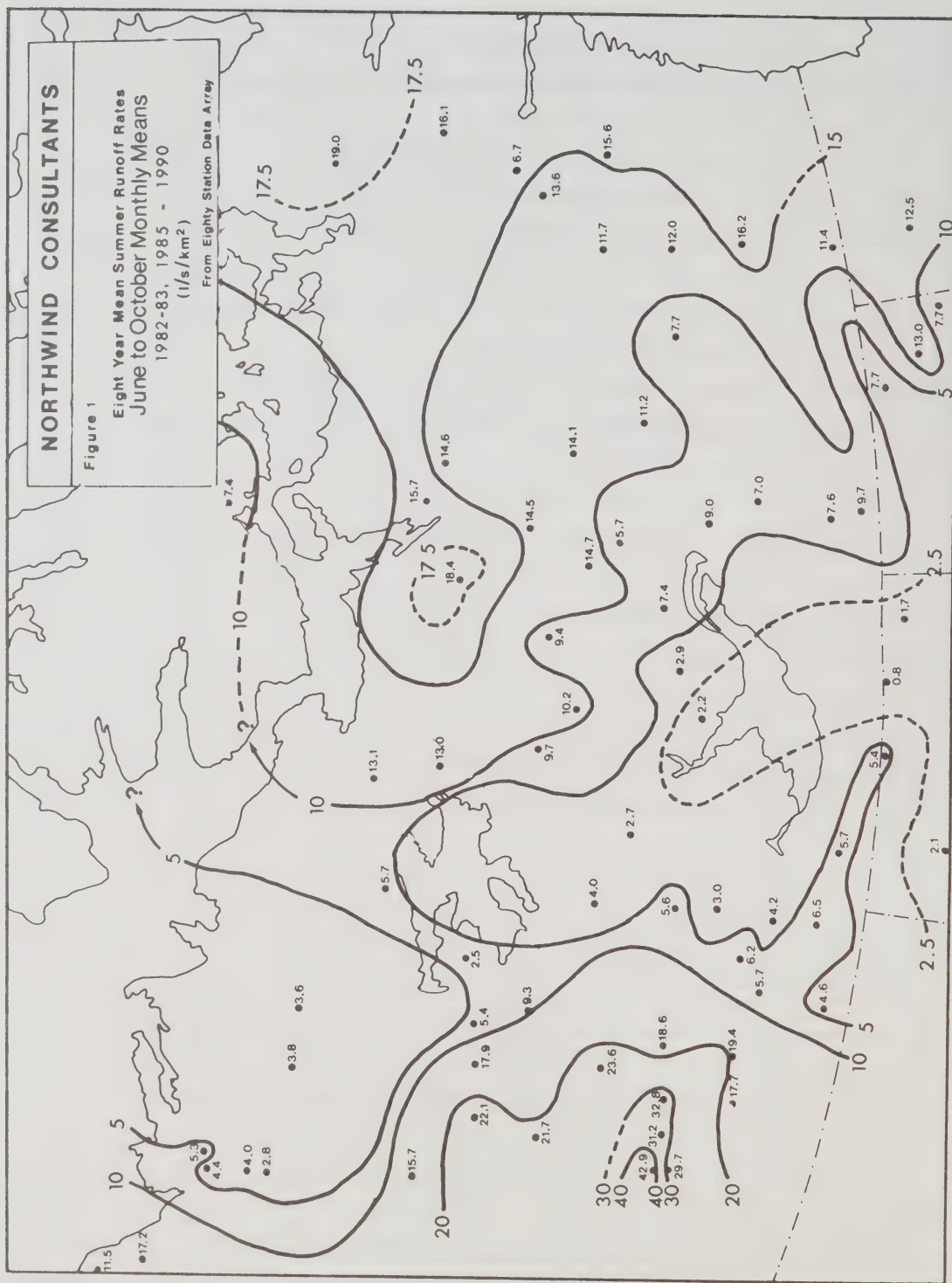
10MD001		5	Firth River near the mouth	YT	
10UH002	*	5	Apex River at Apex	NT	
07QC003	*	6	Thoa River near Inlet to Hill Island Lake	NT	*
07QC004		6	Martin River above Thoa River	NT	
07QD004		6	Taltson River above Porter Lake Outflow	NT	
06MA005		7	Prince River near Baker Lake	NT	
06MB001		7	Quoic River above St. Clair Falls	NT	
06NB002	*	7	Ferguson River below O'Neil Lake	NT	
10SB001	*	7	Hayes River above Chantrey Inlet	NT	
10TF001		7	Freshwater Creek near Cambridge Bay	NT	
06JC002	P	8	Thelon River above Beverly Lake	NT	
06LC003		8	Siuraq Creek near Outlet to Kazan River	NT	
06MA002	*	8	Qinguq Creek near Baker Lake	NT	
10QC002		8	Gordon River near the mouth	NT	
10QD001		8	Ellice River near the mouth	NT	
10RA002		8	Ballie River near the mouth	NT	
06GB001		9	North Seal River Below Stony Lake	MB	
07SA004		9	Indin River above Chalco Lake	NT	
07SB010	*	9	Cameron River below Reid Lake	NT	*
07SC002		9	Waldron River near the mouth	NT	*
10JA004	*	9	Acasta River above Little Crapeau Lake	NT	*
10JB001		9	Johnny Hoe River above Lac Ste. Therese	NT	
10JD001		9	Haldane River near the mouth	NT	
10JE001	*	9	Sloan River near the mouth	NT	
10PC001		9	Kendall River near outlet of Dismal Lakes	NT	
10QC001	*	9	Burnside River near the mouth	NT	
10RA001		9	Back River below Beechy Lake	NT	
10HB004		10	Silverberry River near Little Dal Lake	NT	
10HB005	*	10	Redstone River 63km above mouth	NT	
07PA001	*	11	Buffalo River at Highway 5	NT	
07PB002		11	Little Buffalo River below Highway 5	NT	
10GA001		12	Root River near the mouth	NT	
10GB006	*	12	Willowlake River above Metahdali Creek	NT	
07QB002	*	13	Snowdrift River at outlet of Siltaza Lake	NT	

10EA003		13	Flat River near the mouth	NT	
10EC002	*	13	Prairie Creek at Cadillac Mine	NT	
07NB008		14	Dog River near Fitzgerald	AB	
07SB013	*	14	Baker Creek at outlet of Lower Martin Lake	NT	*
07UC001		14	Kakisa River at outlet of Kakisa Lake	NT	
10FA002	*	14	Trout River at Highway 1	NT	
10HC003	*	15	Big Smith Creek near Highway 1	NT	
10KA007		15	Bosworth Creek near Norman Wells	NT	
06DA002		16	Cochrane River near Brochet	MB	
07LC002		16	Chipman River above Black Lake	SK	
07LC003		16	Porcupine River at Outlet of Grove Lake	SK	
06HB002	*	17	Thlewiaza River above outlet Sealhole Lake	NT	
06LC002	*	17	Kunwak River below Princess Mary Lake	NT	
10PB001	*	17	Coppermine River at Outlet of Point Lake	NT	*
06JB001	*	N	Hanbury River above Hoare Lake	NT	
07PC001	*	N	Buffalo River near Alberta/NWT boundary	NT	
10HC006	*	N	Blackwater River near outlet of Blackwater Lake	NT	*
10OC001	*	N	Inman River near the mouth	NT	
10QA001	*	N	Tree River near the mouth	NT	
10UH001	*	N	Sylvia Grinnel River near Iqaluit	NT	
06MA007	P		Anigag River below Audra Lake	NT	

## Figure 1

Eight Year Mean Summer Runoff Rates  
June to October Monthly Means  
1982-83, 1985 - 1990  
(l/s/km<sup>2</sup>)

### From Eighty Station Data Array

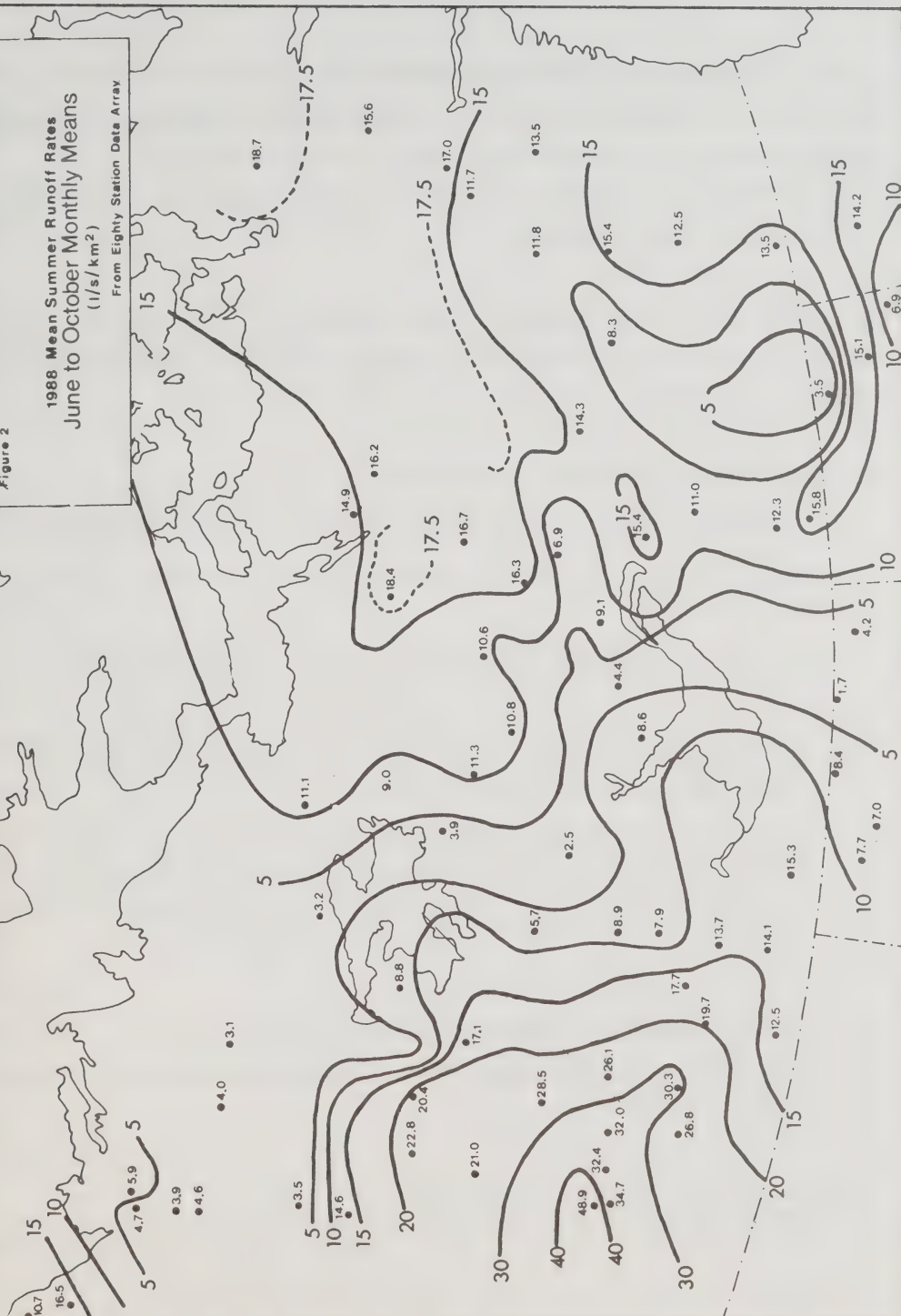


**NORTHWIND CONSULTANTS**

**Figure 2**

1988 Mean Summer Runoff Rates  
June to October Monthly Means  
(l/s/km<sup>2</sup>)

From Eighty Station Data Array.



## **CONCLUSIONS AND FUTURE DIRECTIONS**

This study served as a precursor to detailed hydrologic modelling of regional regimes. It served to identify general areas or regions for individual models within the NWT mainland. The models should include elements such as topography, physiography, climate variables, vegetation, lake and wetland fractions and locations.

Further work may be required to identify physical characteristics of hydrologically similar areas. This would in turn identify the important contributing factors and further the development of methods for estimating flow parameters in ungauged basins.

## **SEVERAL RECOMMENDATIONS WERE MADE:**

1. develop lake/wetland fractions for regional hydrology catchments by imagery analysis;
2. begin the assembly of numerical data banks to support the development of regional hydrologic models;
3. review the operational procedures for field and computational data acquisition and analysis of midwinter low flows, and develop a conceptual low-flow model design;
4. conduct a workshop attended by scientific and operational staff to finalize the proposed 44 master stations identified here, and define the 'area of influence' for each master station if different from these study results; and
5. define the 20-year flood for appropriate regional hydrology stations. In this regard, it should be noted that 20-year flood magnitudes change with increases in the data set. Accordingly, it would be of great benefit to users of hydrometric data to receive annual updates of these data, preferably as isoline maps.

## **PUBLICATIONS AND REPORTS GENERATED**

Northwind Consultants. 1992. NWT Hydrometric Station Regional Hydrology Analysis. Report Prepared Under Contract. 89pp.

## **2.8 RIVERINE INPUTS OF CONTAMINANTS<sup>1</sup>**

### **PROJECT LEADERS**

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### **PROJECT TEAM**

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### **OBJECTIVES**

#### **Short-term:**

To estimate and characterize the total contaminant load delivered by major river systems to the Arctic marine environment, characterize its source and seasonal variability, and assess the controlling biogeochemical processes.

#### **Long-term:**

To investigate and quantify the processes and rates of contaminant transport and transformation in northern riverine systems, assess applicability of existing predictive models and refine as

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<sup>1</sup>Editors' Note: This project is also funded under the AES Northern Contaminants Program. This summary also appears in Environmental Studies No. 72. Synopsis of Research Conducted under the Northern Contaminants Program.

necessary, and develop an understanding of the biogeochemical dynamics of contaminants at the freshwater/marine interface in northern systems.

## **DESCRIPTION**

Northward flowing rivers that drain  $10^7$  km<sup>2</sup> of northern Asia, northern Europe and North America may be major conduits to the Arctic Ocean of contaminants originating from either point sources and/or from atmospheric deposition to the terrestrial ecosystem. While the amount of freshwater flowing into the Arctic Ocean is only ~1% of the inflow of water entering through Fram Strait, rivers have an important effect on the oceanography of the region. Freshwater inflows contribute to the stable, less dense, more productive surface layer. Adjacent to river mouths, they introduce turbid water and establish horizontal density gradients that drive ocean currents. The processes in river systems that control contaminant mobility, timing and rate of provenance to the Arctic marine environment are likely different from those in temperate climates.

Information on contaminant loadings to the Arctic Ocean from any northward flowing river is limited. Prior to the commencement of this study, existing information for North America focused on the Mackenzie River since it is the only major river system. Beyond simple loading data, however, there is also a need to obtain more extensive information on contaminant fate and effects, both within the river system itself and at the freshwater-seawater interface. Moreover, in order to ensure that no major contaminant pathway has been missed, river systems that drain other ecozones (e.g. tundra) and flow into other marine environments (e.g. estuarine versus deltaic) must be considered. Such information can only be obtained in the short-term through an intensive research survey that effectively extends existing data and anticipates long-term monitoring data.

Once completed, this study will provide: 1) good baseline information on the magnitude, source, and spatial and temporal variability of contaminant delivery by river systems to the Arctic Ocean (this information will be used for Canada's Northern Contaminants Program and the Arctic Monitoring and Assessment Programme (AMAP)); 2) a basis for assessing and/or refining

preliminary transport and fate models; and 3) a basis for identifying remaining information gaps to assist planning of further field work.

### **Progress Prior to Fiscal 1993-94**

In 1991-92, a review of existing trace organic contaminant data was undertaken that included a classification of NWT river systems based on hydrology, suspended sediment loads, geology, geomorphology, vegetation and climate. This information was used to design subsequent field sampling programs. In 1992-93, the Mackenzie River was sampled in June, July and August near Inuvik (East Channel), Aklavik (West Channel) and Arctic Red River (Main Channel) for suspended sediment and filterable solids, temperature, conductivity, pH, major ions and a suite of organic contaminants (see below). A survey of 11 rivers (the Anderson and 10 rivers in the District of Keewatin) was conducted in August using the Mackenzie sampling protocol except that only water and suspended solid samples were collected due to the low filterable sediment load in these rivers. Sample processing and laboratory analyses commenced in the fall and winter of 1992-93.

## **ACTIVITIES IN 1994**

### **Sample Collection**

After consideration of preliminary 1992-93 data, follow-up sampling was conducted at all sites in 1993-94 by Sean Backus (contract), Murray Swyripa, Juanetta Peddle (Indian and Northern Affairs Canada) and assisted by Brian Ferguson (Fisheries and Oceans Canada). See Figures 1 and 2 for sample locations. A greater number of field blanks were collected to improve quality control. The three Mackenzie River sites were sampled on three occasions as before to permit evaluation of between-year variability. In addition, to enhance evaluation of seasonal variability, sub-ice sampling in the winter was conducted for the first time. Replicate samples were collected at the Arctic Red River site to assess between-sample variability. The Keewatin sites and the Andrews River site (substituted in 1993-94 for the Anderson River) were sampled once during peak spring flow in July to repeat the 1992 work. A large volume water sample (108 L at the Keewatin sites, the Andrews and at the Arctic Red sites and 40 L at the Inuvik and Aklavik sites) and a suspended sediment or filterable solid sample were collected at each site.

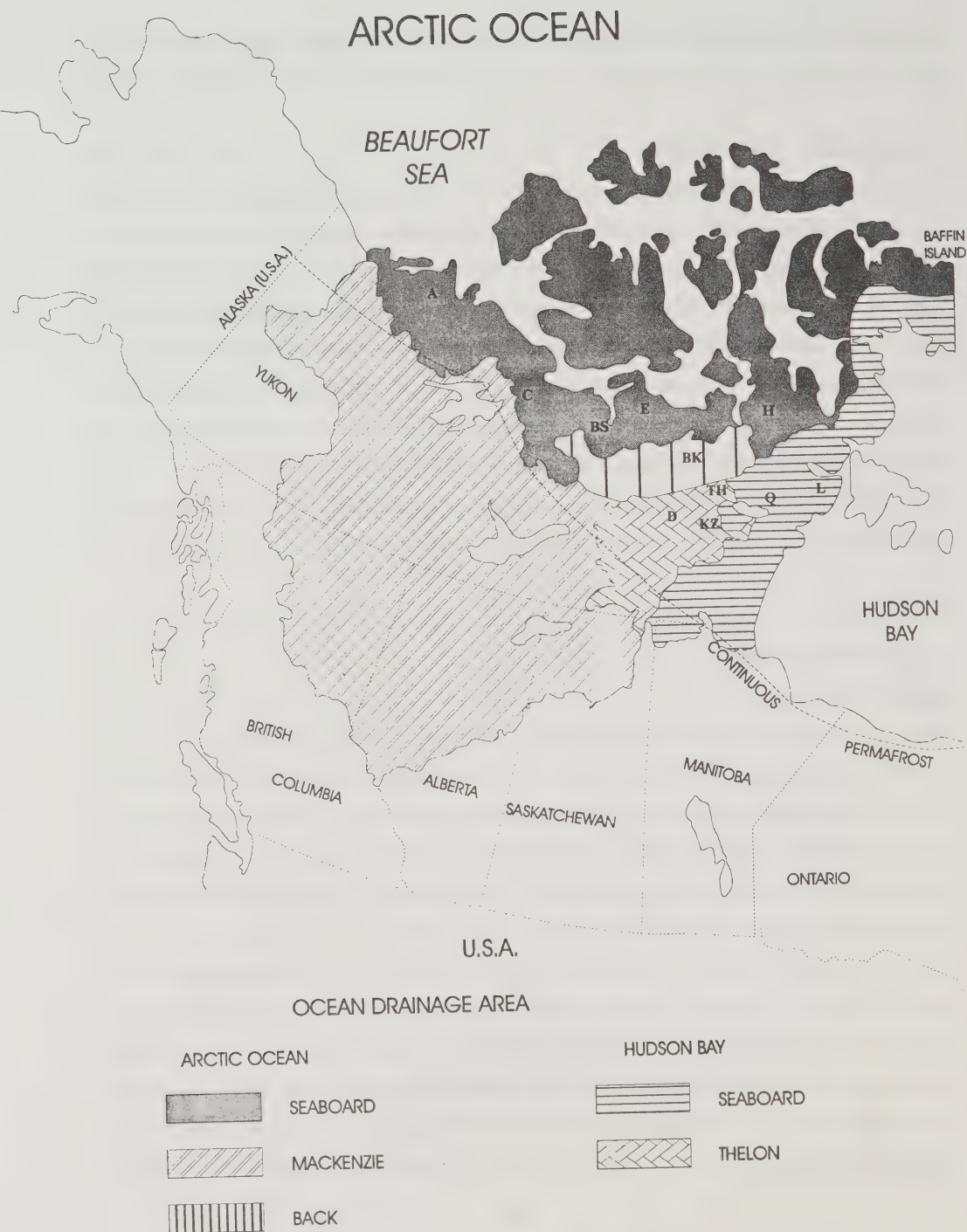


Figure 1. Sampling locations showing drainage basins, 1993-94

## RESULTS

### Sample Analysis

Organochlorines (Ocs) in water: Procedures for the extraction of large volume water samples using the Goulden extractor are given by Neilson *et al.* (1988) and further details on the extraction and cleanup steps are given by Comba *et al.* (1993).

Sediments: Sub-sets of suspended sediments collected from the Mackenzie River were freeze-dried and analyzed for trace metals and particle size analysis. Wet sediments were extracted with hexane:acetone (41:59) in a Soxhlet apparatus using glass thimbles with sintered glass frits. Internal standards of deuterated PAHs and 1,3,5-tribromobenzene and 1,2,4,5-tetrabromobenzene were added after the extraction step. The extract was chromatographed on a silica column (topped with 1 cm sodium sulphate) and eluted with hexane (to recover alkanes) followed by hexane:dichloromethane (1:1) for 2 to 6 ring PAHs. Organochlorines were isolated in the same step.

Capillary gas chromatographic analysis of PCBs, toxaphene, DDT and other organochlorines was carried out on a HP-5890 GC equipped with a 30 m x 0.25 mm x 0.25  $\mu\text{m}$  DB-5 column and a 30 m x 0.25 mm x 0.25  $\mu\text{m}$  OV-1 column. Quantitation of organochlorines was based on dual column confirmation using an external standard. PCBs were measured as individual congeners based on the dual capillary column procedure established at the 1985 PCB workshop in Grosse Ile, Michigan (Mullin *et al.* 1985). Initial quantitation of PCB congeners was carried out using the primary Green Bay (GB) Mass Balance PCB standard (Swackhamer *et al.* 1988) obtained through the University of Minnesota. The GB PCB standard is a mixture of Aroclors 1232, 1248, and 1262 from the Quality Assurance Branch, U.S. EPA, Cincinnati, Ohio, in the ratio of 25:18:18. Individual congener concentrations were calibrated by Mullin (Mullin *et al.* 1985) for this specific PCB standard. A second primary PCB standard was prepared using purchased Aroclor solutions of 200  $\mu\text{g}.\text{ml}^{-1}$  1016, 1221, 1242, 1254 and 1262 at ratios of 1:1:1:1:1 and reconstituted in hexane to a concentration of 1  $\mu\text{g}.\text{ml}^{-1}$ . This secondary PCB standard was calibrated with the primary GB standard and verified using all 209 individual PCB congeners.

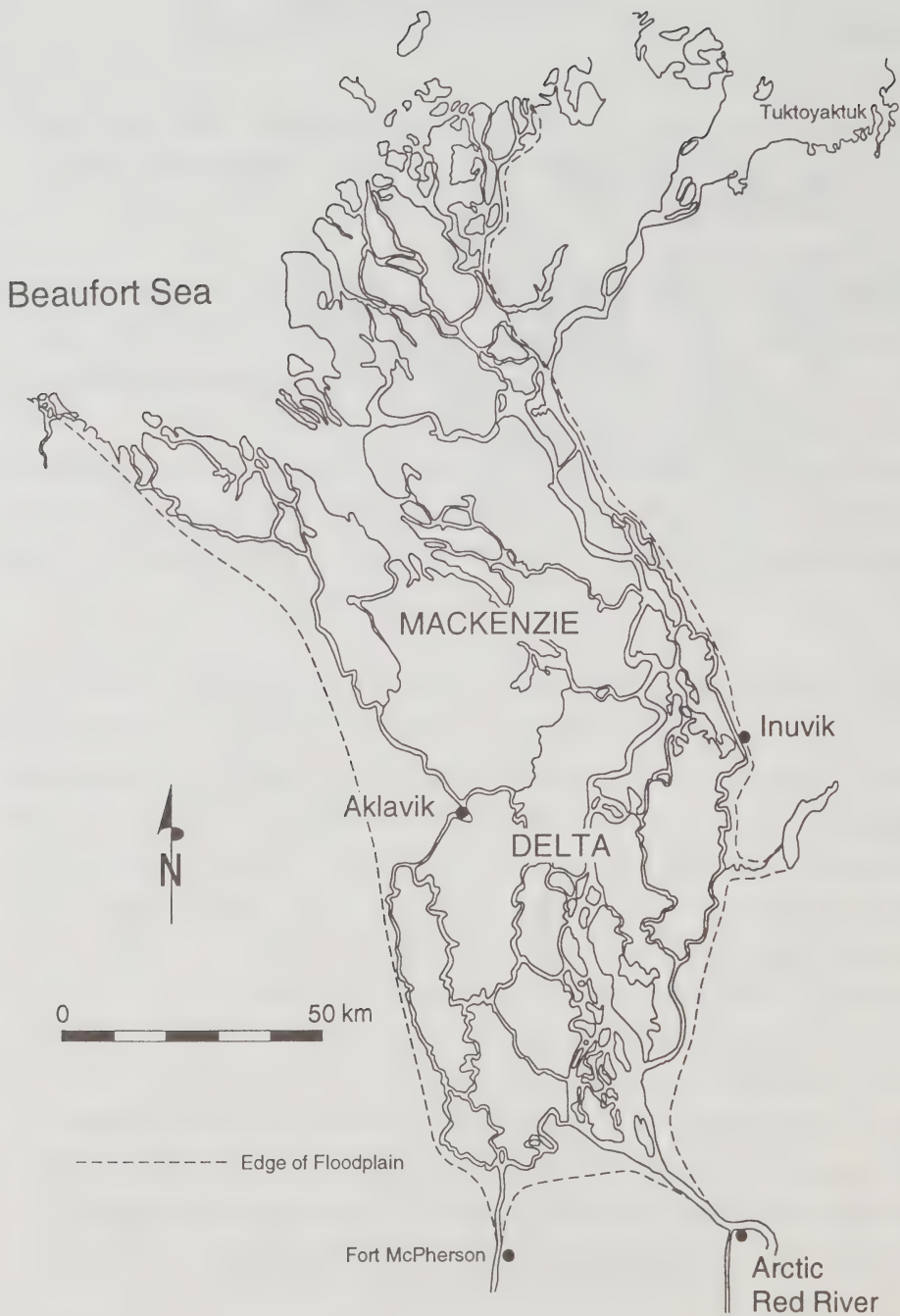


Figure 2. Sampling locations on the Mackenzie River 1993-94

PAHs were quantified by capillary GC-mass spectrometry (HP 5890-5971 MSD) using an external standard technique.

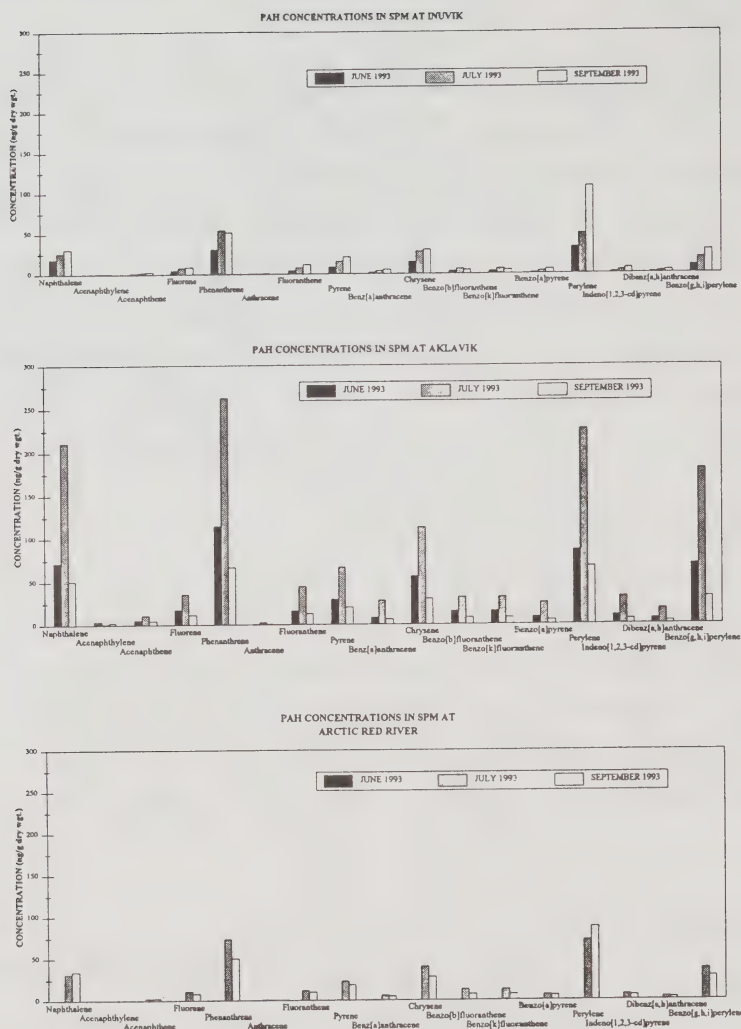
Beyond the physical and inorganic variables, both the dissolved and particulate phase samples have been analyzed for 8 chlorobenzenes, 20 organochlorine pesticides, 120 PCB congeners, 17 PAHs, several alkylated PAHs and acyclic hydrocarbons and are currently being analyzed for toxaphene by GC-NIMS. The currently available raw data show that most samples have total PCBs and other OC values below detection limits after blank correction. A small number of OC variables (e.g. HCH) are occasionally detectable. The PAH concentrations in the particulate phase are shown graphically in Figures 3, 4 and 5. Obviously there are substantial spatial and temporal differences in particulate phase PAH levels found at the 3 Mackenzie sites (Figure 3). Similarly, large differences exist among the 10 Keewatin rivers (Figures 4 and 5).

### **Quality Assurance/ Quality Control (QA/QC)**

The laboratories participating in this project include several at Environment Canada's National Water Research Institute (NWRI) and the Indian and Northern Affairs Water Resources, Water Laboratory in Yellowknife. The NWRI laboratories participate in the Northern Contaminants QA/QC Program. Within study QA/QC is extensive and is designed first, to identify when the entire procedure does not function according to specifications, and second, to determine which sub-procedure has failed (e.g. contaminant isolation, pre-analysis concentration, fractionation, etc.).

### **General Water Quality and Metals**

Results of the analyses for trace metals, nutrients, and physical variables are summarized in Tables 1 and 2. In general, the rivers have low levels of filterable and non-filterable residues, low hardness and alkalinity, and low nutrient levels. Metal levels were also generally very low. The Andrews River water quality differs significantly from the other sites.



Note: Sampling at Arctic Red River was not completed in June because of mechanical problems with the centrifuge.

Figure 3. PAH Distributions in Suspended Particulate Matter in the Mackenzie Delta.

# PAH Distributions for Arctic Rivers

July 1993

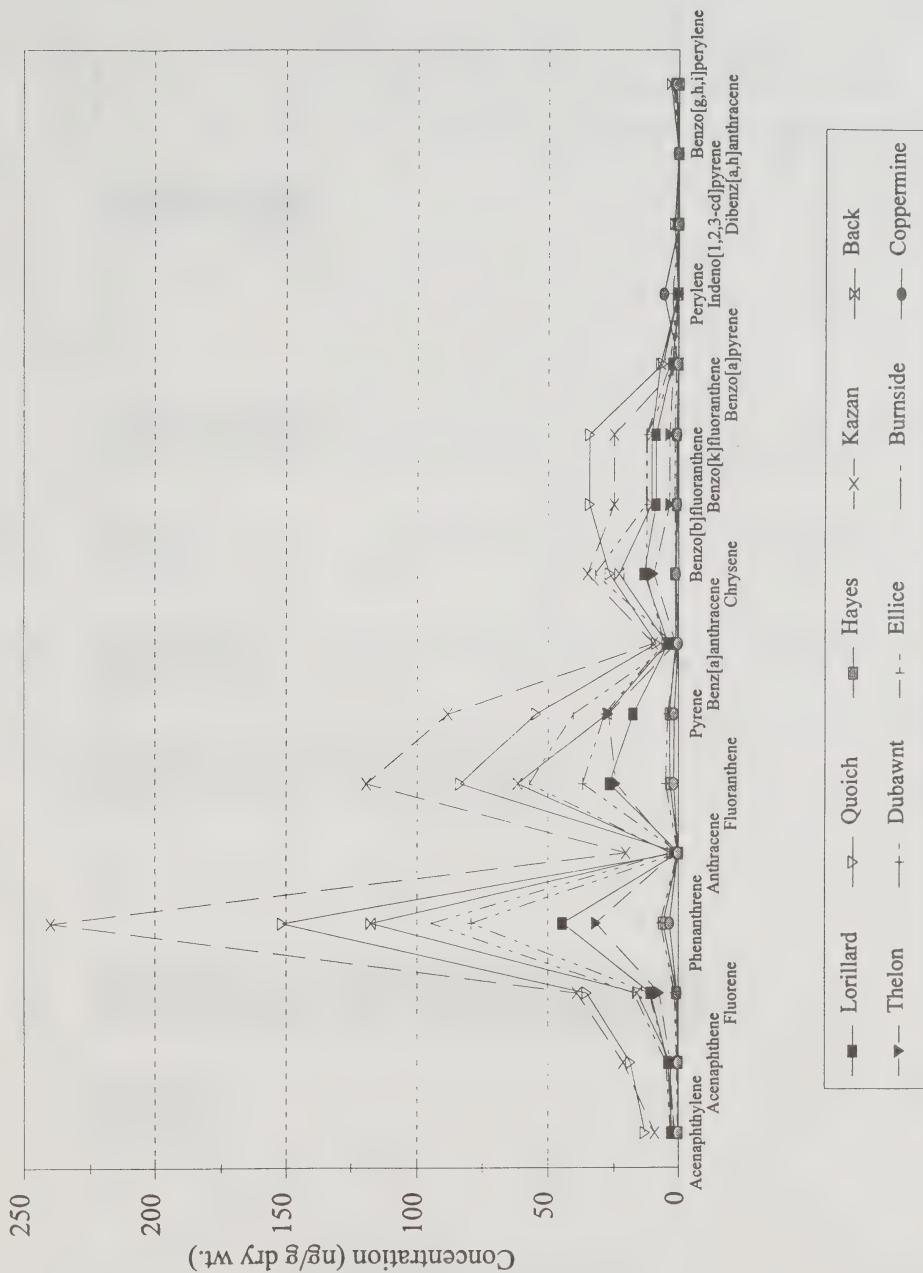


Figure 4. PAH Distributions in Suspended Particulate Matter of Arctic Rivers.

# Total PAH Distributions

July 1993

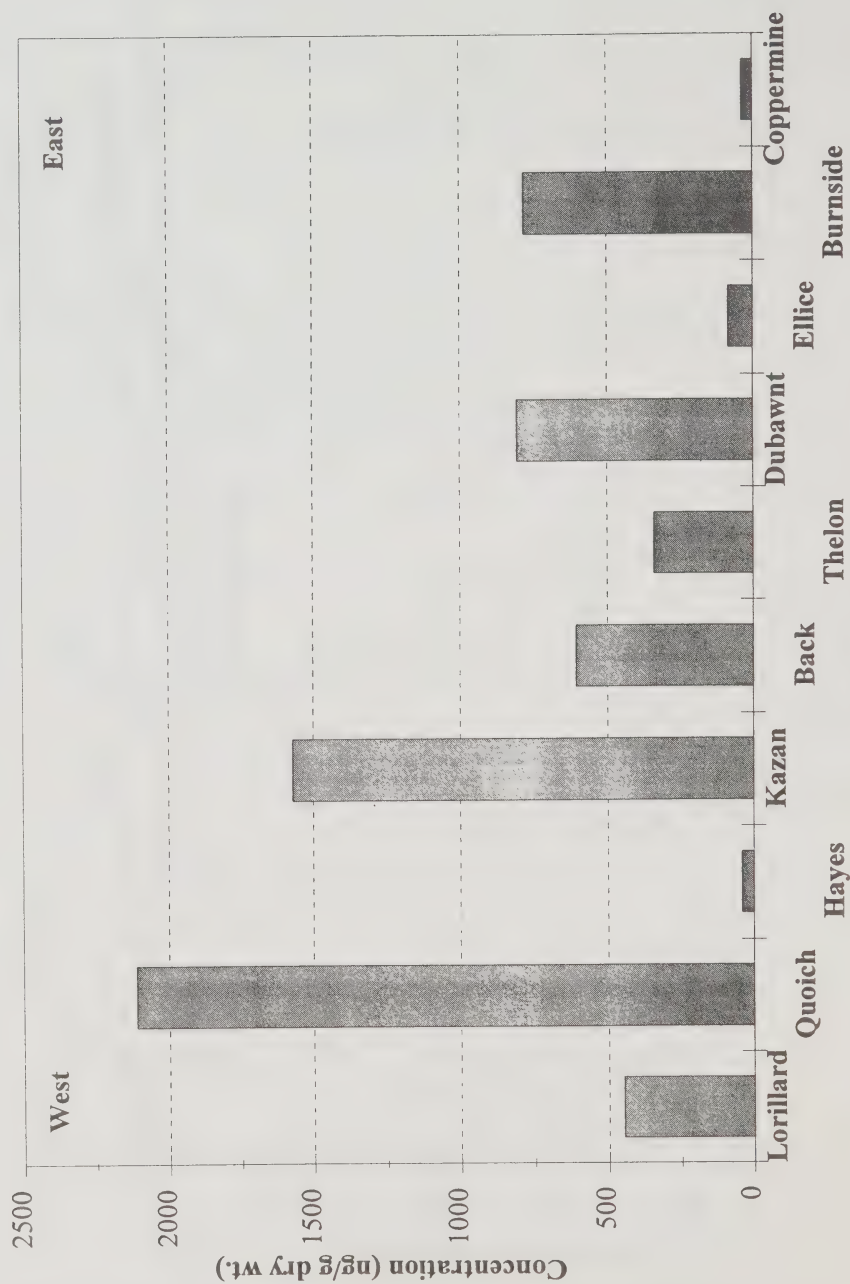


Figure 5. Total (16 Priority) PAH Distributions in Suspended Particulate Matter of Arctic Rivers.

## **DISCUSSION**

The analyses of these samples were completed in 1993-94, and the data are still under review and evaluation. In this regard, the data presented in the tables and figures should be considered preliminary at this time. Upon receipt of flow data in early July 1994, river loadings will be calculated.

**Expected completion date:** March 31, 1997

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Table 1. Keewatin Rivers Field Data

	Coppermine	Burnside	Ellice	Dubawnt	Thelon	Back	Kazan	Hayes	Quoich	Lorillard
Latitude (N)	67° 13' 45"	66° 43' 26"	67° 42' 29"	64° 13' 52"	64° 46' 23"	66° 05' 10"	63° 39' 10"	67° 31' 30"	64° 18' 22"	64° 17' 36"
Longitude (W)	115° 53' 11"	108° 48' 40"	104° 08' 19"	99° 28' 37"	97° 04' 04"	96° 30' 15"	95° 51' 19"	94° 05' 19"	93° 55' 02"	90° 26' 49"
Sampling Date	20/7/93	20/7/93	20/7/93	22/7/93	22/7/93	21/7/93	22/7/93	21/7/93	21/7/93	21/7/93

	Coppermine	Burnside	Ellice	Dubawnt	Thelon	Back	Kazan	Hayes	Quoich	Lorillard
pH	8.19	7.94	7.87	7.86	7.74	6.72	7.04	6.23	7.62	7.84
Turbidity	112	0	11	8.0	313	122	0	31	0	2
Salinity	0	0	0	0	0	0	0	0	0	0
D.O. (mg/L)	10.67	11.10	10.53	10.78	14.42	11.16	11.40	9.42	10.07	10.15
Conductivity (ms/cm)	0.056	0.013	0.015	0.013	0.017	0.012	0.018	0.005	0.006	0.006
Temperature (°C)	10.8	11.4	16.4	10.1	6.1	11.5	14.0	17.8	18.7	15.6
SPM (mg/L)	26.4	0.93	8.4	1.2	1.3	1.1	0.3	9.2	0.3	1.1
DOC (mg/L)	7.1	1.6	0.8	1.3	2.1	1.1	1.8	0.6	0.4	0.3
DOC (mg/L)	7.5	4.2	7.6	8.5	21.5	4.2	8.2	8.4	27.3	13.2
POC (mg/L)	0.388	0.121	0.328	0.401	0.262	0.268	0.193	0.414	0.221	0.114
PON (mg/L)	0.041	0.012	0.028	0.040	0.03	0.024	0.017	0.039	0.028	0.013
DOC/POC	19	35	23	20	82	16	42	20	124	94

D.O. = Dissolved Oxygen  
 SPM = Suspended Particulate Matter  
 DIC = Dissolved Inorganic Carbon  
 DOC = Dissolved Organic Carbon  
 POC = Particulate Organic Carbon  
 PON = Particulate Organic Nitrogen

Table 2. Major ions, nutrients, metals and physical variables for the Arctic Rivers. Triplicate samples were collected at the Andrews and Hayes Rivers; mean and standard deviation are shown.

Sampling Date	Andrews (n=3)	Coppermine 20/7/93	Burnside 20/7/93	Ellice 20/7/93	Dubawnt 22/7/93	Thelon 22/7/93	Back 21/7/93	Kazan 22/7/93	Hayes (n=3) 21/7/93	Qoich 21/7/93	Lonillard 21/7/93
Alkalinity (mg/L)	88.7 ± 0.08	27.2	4.2	1.6	3.8	4.7	2.7	6.2	<0.3	<0.3	<0.3
Calcium (mg/L)	26.87 ± 0.09	6.40	1.40	1.00	1.50	1.70	1.00	2.00	0.4 ± 0	0.50	0.40
Chloride (mg/L)	2.02 ± 0.02	0.43	0.37	1.84	0.44	0.90	0.66	0.40	0.67 ± 0.004	0.53	0.63
Colour	18 ± 5	12	<5	12	<5	<5	<5	<5	11 ± 2	<5	<5
Tot. Hardness (mg/L)	95.7 ± 0.5	29.0	6.0	5.0	5.8	7.1	5.0	7.9	<3	<3	<3
Potassium (mg/L)	1.20 ± 0	0.40	0.30	0.30	0.30	0.40	0.30	0.20	0.27 ± 0.05	0.20	0.30
Magnesium (mg/L)	7.00 ± 0.05	3.10	0.60	0.60	0.50	0.70	0.60	0.70	0.20 ± 0	0.20	0.20
Sodium (mg/L)	4.80 ± 0	0.50	0.40	1.20	0.40	0.50	0.40	0.40	0.53 ± 0.05	0.50	0.50
T-Phosphorous (mg/L)	0.006 ± 0	0.007	0.002	0.009	<0.002	<0.002	0.003	<0.002	0.008 ±	0.002	0.014
Non-Fill Res (mg/L)	<3	4	<3	<3	<3	<3	<3	<3	5 ± 2	<3	<3
Ammonia-N (mg/L)	0.014 ± 0.003	0.004	0.005	0.009	0.016	0.011	0.158	0.027	0.017 ±	0.019	0.007
NO <sub>3</sub> +NO <sub>2</sub> -N (mg/L)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Ortho-Phos (mg/L)	<0.002	<0.002	0.003	0.005	<0.002	<0.002	0.002	0.018	0.006 ± 0	<0.002	<0.002
pH	8.18 ± 0.01	7.40	6.71	6.51	6.63	6.63	6.53	6.89	6.17 ± 0.02	6.14	6.15
Sulphate (mg/L)	14.4 ± 0.6	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
T. Arsenic-Hyd (µg/L)	0.3 ± 0	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
T. Cadmium-S/E (µg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
T. Cobalt-S/E (µg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
T. Chromium-S/E (µg/L)	<1	<1	<1	<1	<1	<1	<1	<1	1 ± 0	<1	<1
T. Copper-S/E (µg/L)	1 ± 0	2	1	1	<1	<1	<1	<1	1 ± 0	<1	<1
T. Iron-S/E (µg/L)	327 ± 40	374	170	397	105	82	152	56	626 ± 30	128	75
T. Mercury-C/V (µg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
T. Nickel-S/E (µg/L)	2 ± 0.5	1	1	<1	<1	<1	<1	<1	1 ± 0	<1	<1
T. Lead-S/E (µg/L)	1 ± 0	<0.7	<0.7	1	<0.7	<0.7	1	<0.7	1.3 ± .5	<0.7	<0.7
T. Zinc-S/E (µg/L)	2.0 ± .8	1.0	3.0	1.0	1.0	<1	1.0	<1	1.3 ± .5	1.0	<1
Turbidity (NTU)	3.0 ± 0.3	4.8	0.8	8.5	0.6	0.7	1.1	0.6	9.0 ± .7	1.1	0.6



## **2.9 INVESTIGATION OF MERCURY IN LAC STE. THÉRÈSE**

### **PROJECT COORDINATOR**

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### **PROJECT OBJECTIVE**

To investigate the historically high mercury concentrations in fish from Lac Ste. Thérèse.

### **DESCRIPTION**

The Canadian Arctic is perceived by the general public to be a pristine environment, completely free of contamination. This is not the case. Global atmospheric deposition of anthropogenic contaminants and local physiographic factors can impact on the quality of northern ecosystems (Barrie *et al.*, 1992). The presence of mercury within the ecosystem is generally well documented. Lower levels are normally associated with either natural or long- range transport from anthropogenic sources while higher levels are usually the result of some direct anthropogenic source, such as mining or dams (Lindqvist, 1985; Zillioux *et al.*, 1993). The elevated mercury levels in Lac Ste. Thérèse, a remote lake in the Johnny Hoe River Basin, Northwest Territories are of interest because there is no development within the Basin. This study examines the relationship of mercury concentration in fish from Lac Ste. Thérèse over time and compares the results to other lakes within the Basin.

#### **Location:**

Lac Ste. Thérèse was the primary sampling site to determine if the historically high mercury values were still relevant to any future discussions about the lake in light of land claims. Other lakes (Keller Lake, Lac Tachè and Tseepantee Lake) in the Johnny Hoe River Basin (Figure 1) were sampled to determine if high mercury concentrations in fish are consistent throughout the

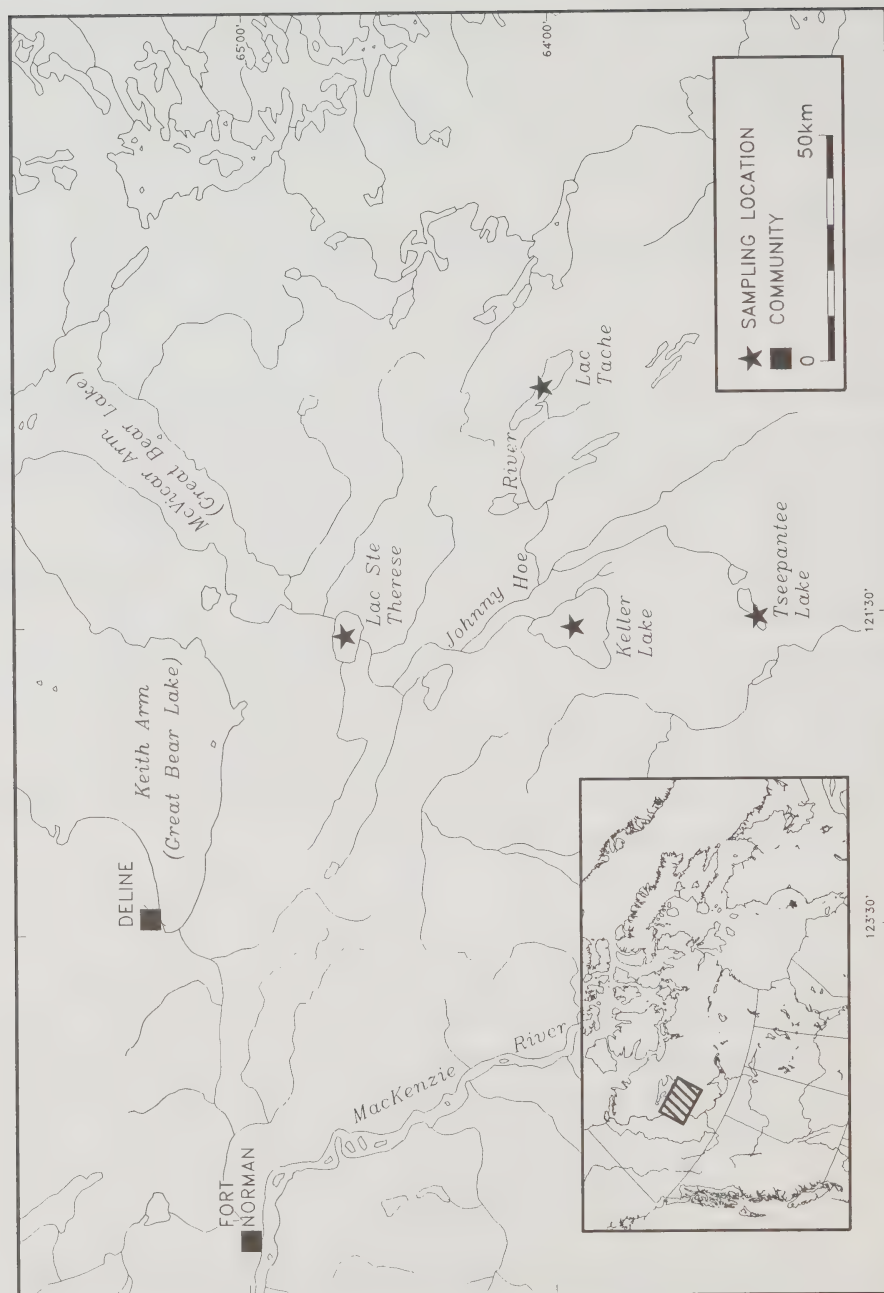


Figure 1 Location of Lac Ste. Therèse sampling sites.

Basin. The water quality is similar for all of the lakes with only minor differences (G.R. Stephens, unpublished data).

### **Sampling Methods**

The collection of fish species was prioritized by their importance for both human health consumption and the ecosystem. Top level piscivores such as walleye (*Stizostedion vitreum*) and lake trout (*Salvelinus namaycush*) were the primary focus. Northern pike (*Esox lucius*) was also sampled because it is not generally restricted by lake chemistry as are walleye and lake trout. Lake whitefish (*Coregonus clupeaformis*) was collected since it represents a lower trophic feeder found in most northern Canadian lakes.

Fish were collected from Lac Ste. Thérèse in August 1992 and 1993, using 89 mm and 115 mm mesh gill nets with multiple sets of 4 to 8 hours in duration. The other three lakes were sampled in August 1993 using the same equipment and timing. In all instances, basic biological data were recorded including total length, weight and sex. The appropriate ageing structures were recovered. A boneless, skinless fillet (approximately 100 g) was collected from the area lateral and ventral to the dorsal fin. Each sample was placed in a whirl pack bag and frozen before being shipped to the Environmental Chemistry Lab at the Freshwater Institute in Winnipeg, Manitoba. Total mercury concentrations were determined using the method described by Hendzel and Jamieson (1976).

### **RESULTS**

The reported mean mercury concentrations are unadjusted for length, weight or age of fish since both simple and exponential regression analysis showed no significant correlation.

#### **Temporal Trends in Lac Ste. Thérèse:**

When the data collected in 1992 and 1993 for Lac Ste. Thérèse are compared with the 1975 (walleye) and 1980 (walleye, lake trout and northern pike) data from the Department of Fisheries and Oceans Inspection Services Branch (Hendzel, pers. comm.), they create an 18-year record of mercury concentrations in walleye and a 13-year record for lake trout and northern pike. There

Table 1. Historic unadjusted mercury concentrations and biologic information for fish from Lac Ste. Thérèse.

YEAR	SPECIES	MERCURY (ppm)		LENGTH (mm)		WEIGHT (g)		AGE (years)	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
1975	Walleye	1.00	0.59-1.43	484	438-565	1126	907-1643	-	-
1980	Walleye	1.39	1.09-1.82	505	472-553	1457	824-1884	-	-
1980	Lake Trout	1.25	0.80-2.52	849	700-1012	6962	4068-11291	-	-
1980	Northern Pike	1.45	0.62-2.51	841	729-985	4380	2674-6387	-	-
1992	Walleye	1.34	0.71-2.31	463	410-520	1016	700-1400	15	9-20
1992	Lake Trout	0.949	0.68-1.40	658	620-688	2638	2250-3100	21.5	16-27
1992	Northern Pike	0.914	0.37-1.78	736	600-994	3079	1550-6300	11.7	6-21
1992	Lake Whitefish	0.132	0.044-0.50	463	410-503	1324	850-1750	13	9-17
1993	Walleye	1.48	0.29-1.99	452	387-507	891	655-1191	13.9	9-17
1993	Lake Trout	1.34	1.34	667	599-714	2593	2148-3018	35.5	32-39
1993	Northern Pike	0.735	0.25-1.09	684	535-750	2347	1160-2873	8.0	6-11
1993	Lake Whitefish	0.372	0.079-1.86	439	333-535	1103	445-2090	14.7	3-30

is no historic information available for lake whitefish in Lac Ste. Thérèse. Table 1 illustrates the unadjusted mean mercury concentrations in walleye, lake trout, northern pike and lake whitefish from Lac Ste. Thérèse over time. Both walleye and lake trout continued to have high unadjusted mean mercury concentrations. The concentrations in pike appear to have decreased along with mean length and weight. For all species, the 1980 samples had higher mean lengths and weights than the 1992 or 1993 samples. The lake whitefish had higher unadjusted mean mercury concentrations in 1993 than in 1992, while the mean length and weight have decreased.

#### **Areal extent within the Johnny Hoe River Basin:**

Table 2 summarizes the results of the comparison of mercury concentrations in walleye, lake trout, northern pike and lake whitefish from the four lakes within the Basin for 1993. Not all of the species (walleye and lake trout) found in Lac Ste. Thérèse were present in all lakes. For all species the unadjusted means for mercury concentrations in Lac Ste. Thérèse fish were higher than those in the other lakes. While there might have been differences in length or weight between lakes, the ages of the fish were always similar.

### **DISCUSSION**

The results indicate that mercury concentrations in fish from Lac Ste. Thérèse have remained high over time implying that mercury input has been relatively constant. Since data are not standardized, it is difficult to make definitive conclusions regarding the trend of mercury concentrations.

The comparison of lakes within the Basin reveals that Lac Ste. Thérèse has the highest mercury concentrations in fish regardless of the species. While more work is required to accurately determine the reasons for these differences, higher mercury concentrations can generally be attributed to water quality and basin morphology (Håkanson *et al.*, 1988; Wiener *et al.*, 1990; Bodaly *et al.*, 1993). Lac Ste. Thérèse is a brown-water lake located at the mouth of the Basin. Tseepantee Lake has the second highest unadjusted mercury levels and is also a brown-water lake but located at the headwaters of the Basin. It is also a smaller, shallower lake than Lac Ste. Thérèse. Both Keller Lake and Lac Taché are clear-water lakes that are part of independent

Table 2 . 1993 unadjusted mercury concentrations and biological information for fish from the lakes within the Johnny Hoe River system.

LOCATION	SPECIES	MERCURY (ppm)		LENGTH (mm)		WEIGHT (g)		AGE (years)	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Lac Ste. Thérèse	Walleye	1.48	0.29-1.99	452	387-507	891	655-1191	13.9	9-17
Lac Ste. Thérèse	Lake Trout	1.34	1.34	667	599-734	2593	2148-3018	35.5	32-39
Lac Ste. Thérèse	Northern Pike	0.735	0.25-1.09	684	535-750	2347	1160-2873	8.0	6-11
Lac Ste. Thérèse	Lake Whitefish	0.372	0.079-1.86	439	333-535	1103	445-2090	14.7	3-30
Keller Lake	Lake Trout	0.412	0.22-1.05	560	495-766	1811	1390-4325	19.6	8-32
Keller Lake	Northern Pike	0.445	0.445	769	769	2917	2917	-	-
Keller Lake	Lake Whitefish	0.064	0.036-0.12	480	377-596	1450	650-2370	12.6	7-32
Lac Taché	Lake Trout	0.345	0.13-0.59	662	556-774	2738	2029-4025	24.8	8-37
Lac Taché	Northern Pike	0.347	0.13-0.68	689	520-987	2528	1000-6750	9.2	4-15
Lac Taché	Lake Whitefish	0.068	0.025-0.14	402	312-500	797	420-1625	12.7	7-22
Tseapuntse Lake	Walleye	0.926	0.25-1.42	439	364-479	820	531-973	16.9	11-23
Tseapuntse Lake	Northern Pike	0.475	0.39-0.71	512	453-557	770	565-870	7.5	6-8
Tseapuntse Lake	Lake Whitefish	0.102	0.037-0.16	425	345-460	1161	642-1440	11.7	6-21

subcatchments. Keller Lake is a larger, deeper lake and this is possibly reflected in the higher mercury concentrations for lake trout and northern pike.

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## **2.10 CHEMISTRY OF WINTER LOW FLOWS IN THE YUKON TERRITORY<sup>1</sup>**

### **PROJECT COORDINATORS**

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### **PROJECT OBJECTIVE**

To understand the effects of geology on water chemistry in Yukon streams.

### **DESCRIPTION**

Water chemistry is controlled by three factors: rock dominance, precipitation and evaporation (Gibbs, 1970). In most of the world, rock dominance is the major determining factor (Gibbs, 1970; Whitfield, 1983; Yurelich and Batchelder, 1988; Psenner, 1989; Kilham, 1990; Catalan *et al.*, 1993). The contribution from soils and bedrock to stream chemistry is the principal interest of this work. Data collected from pristine watersheds throughout the Yukon during the period of winter baseflow provides an indication of the effects that geology has on water chemistry.

The basic characteristics of a water can best be determined during the interval when the dilution and erosion effects of runoff are smallest. Many water quality variables are found to have their

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<sup>1</sup>Editors' Note: This study was a joint project of DIAND, Whitehorse and Environment Canada, Vancouver. A scientific paper based on this study is published by the authors (Whitfield *et al.*, 1994) in the Proceedings of the Workshop on Environmental Aspects of River Ice held in Saskatoon, Saskatchewan, August 1993.

highest concentrations during this period of the year while other variables are at their lowest concentrations (Whitfield and Whitley, 1986; Whitfield and Clark, 1991). Variables which are at their highest concentrations during this time interval are those which are contributed by the dissolution of material in soils and bedrock. Variables which are at their lowest concentrations during this interval are those which enter water courses through erosion or other contributing processes (Whitfield and Whitley, 1986; Whitfield and Clark, 1991). The winter period is characteristic of, and critical to, Yukon ecosystems and other northern areas (Schreier *et al.*, 1980; Whitfield and McNaughton, 1983; Schallock and Lotspietch, 1977).

In most water quality studies, the contributions of individual processes to stream chemistry are difficult to separate (Hornung *et al.*, 1986). In the long and often extreme Yukon winters, rivers have an extensive winter flow recession (Janowicz, 1990). In this study, data were collected near the end of the recession to maximize the groundwater portion of the flow.

**Study Area:** The Yukon Territory is composed of five major drainage basins: Alsek, Yukon, Liard, Peel and North Slope (Figure 1). The rivers in the Yukon drain into the Pacific Ocean, the Bering Sea and the Arctic Ocean. Drainage patterns for these systems are indicated in Figure 1. The Yukon River watershed, including the Porcupine drainage, occupies most of the Territory.

**Sampling Program:** From mid-February to late March 1992, 61 streams and rivers in the Yukon were sampled (Table 1). The stations reflect a variety of sizes of watersheds and geographical units within the Yukon. Flow measurements were made for all stations.

**Methods:** Water samples were collected through ice or in open water using sampling procedures described in detail in written protocols (Environmental Surveys Branch, 1991). Analyses of metal concentrations were performed at the National Laboratory for Environmental Testing, Burlington, Ontario. The others were performed at the Conservation and Protection Laboratory, West Vancouver, B.C. Analytical methods in each laboratory, including laboratory quality assurance, were carried out according to standard procedures.

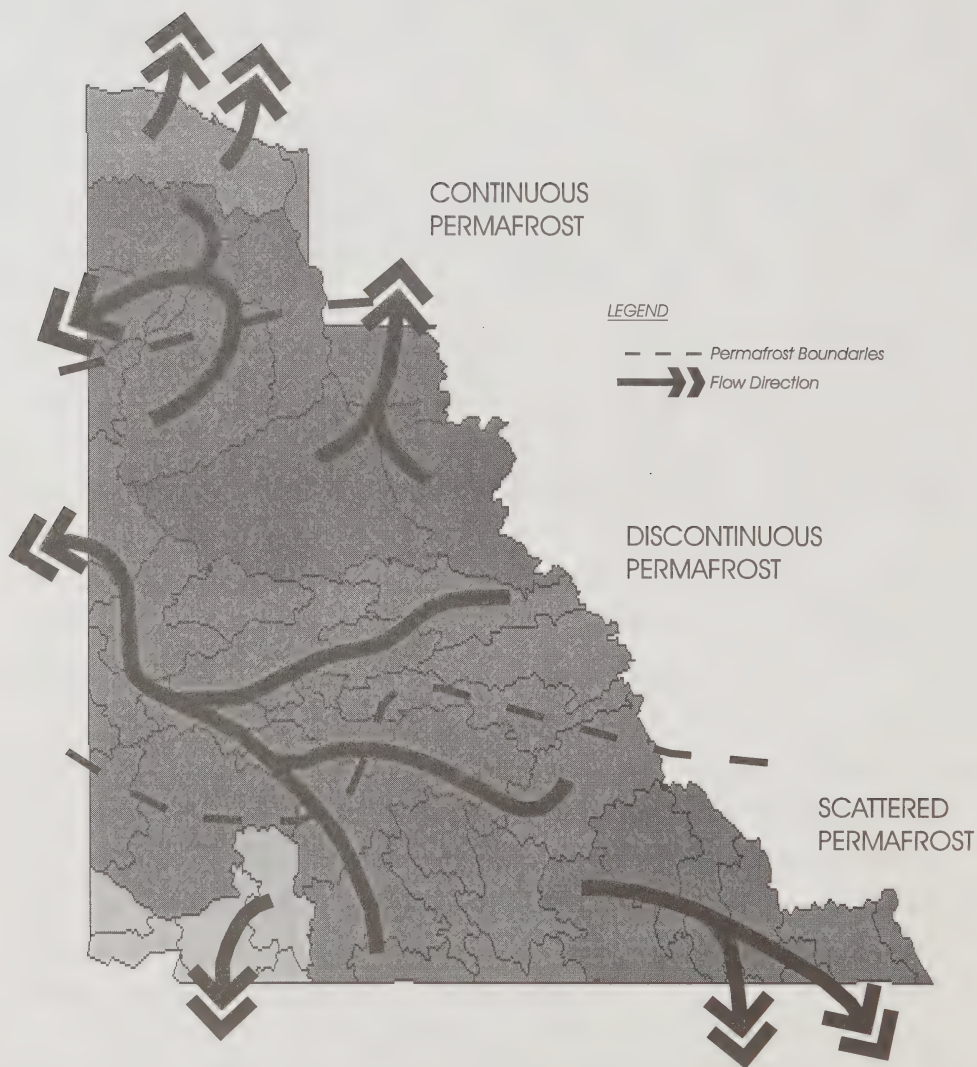
Table 1.  
Source and Collector Streams

Source Streams	Collector Streams
Alsek River above Bates Creek	
Big Creek near mouth	
Big Creek at km 1084.8 Alaska Hwy	
Salmon River near Carmacks	
Blackstone River near Champion Lake	
Bonnet Plume River above Gillespie	
Doniak River below Klane River	
Duke River near mouth	
Eagle River at Demster Hwy bridge	
Fishing Branch River at fisheries weir camp	
Fortymile River near mouth	
Frances River near Watson Lake	
Hart River near Hungry Lake	
Hesse River above Emerald Creek	
Hooie River near mouth	
Hyland River at km108.5 Nahanni Range	
Road lbex River near Whitehorse	
Indian River above mouth	
Ketta River at Robert Campbell Hwy	
Klondike River above Bonanza Creek	
Little South Klondike below Ross Creek	
Macmillan River near mouth	
McClintock River near Whitehorse	
Mcquesten River near mouth	
Miner River upstream of Fishing Branch River	
Nisling River near mouth	
Nisutlin River above Wolf River	
River below Rowlinson Creek	
North Klondike River near mouth	
Ogilvie River 2 km downstream Dempster Hwy bridge	
Old Crow River near mouth	
Peel River above Canyon Creek*	
Pelly River below Fortin Creek*	
Porcupine River below Bell River*	
Rancheria River near mouth	
Red River	
Ross River at Ross River	
Sidney Creek at km 46 Canol Road	
Sixtymile River near mouth	
Snag Creek at km 1945.6 Alaska Hwy	
Snake River near mouth	
South Big Salmon River below Livingstone Creek	
South MacMillan River at km 407 Canol Road	
Stewart River at Mayo (winter section)*	
Takhanne River at km 167 Haines Hwy	
Tatshenshini River near Dalton Post	
Tay River near mouth	
Tom Creek at km 34.9 Robert Campbell Hwy	
Wheaton River below Dail Creek	
White River at km 1881.6 Alaska Hwy	
Whitestone River near mouth	
Wind River near mouth	
Wolf Creek near Whitehorse	
Yukon River at Marsh Lake*	
	Liard River at Fort Liard
	Liard River at Upper Crossing
	Pelly River below Vangorda Creek
	Pelly River at Pelly Crossing
	Porcupine River at International Boundary
	Porcupine River at Old Crow
	Stewart River at mouth
	Yukon River above White R
	Yukon River at Carmacks
	Yukon River at Eagle, Alaska.

Source streams marked \* were also considered as part of the collector stream group.

Figure 1

# DRAINAGE BASINS OF YUKON TERRITORY



Replicate samples and field blanks were collected at every fifth site. Replicate sampling showed only minor variations between replicates and confirmed repeatability. Variations were on the order of analytical precision and were not significant. Results from field blanks were the same as samples that had never left the laboratory. There was no contamination of field samples.

Same system streams were separated into two groups: source streams and collector streams. This eliminated the problem of relating lower order streams to higher order streams. Source streams include the lowest order sampled; each watershed is independent of the others. The collector streams include all those combining the flows of upstream stations and a few source streams from large drainages. Source streams reflect the watershed concentrations more clearly.

Winter flows in Yukon consist predominately of groundwater. Winter groundwater flows estimated using the UBC Watershed model (Quick and Pipes, 1977) confirm the dominance of groundwater during this period.

Water chemistry data were incorporated into a RAISON geographic information system to produce concentration maps.

## **RESULTS**

Preliminary analysis of water chemistry data reveal that all streams can be classified as calcium magnesium types. They are predominately bicarbonate except for two sulphate streams, Eagle River and South MacMillan River. Calcium concentrations are highest in areas where the parent material is calcareous particularly in the Mackenzie platform. Watersheds with low calcium concentrations are associated with volcanic and metamorphic complexes. Gibbs (1970) suggests that calcium is the major cation that can be used for characterizing freshwater. Anion concentrations show that the waters are quite young; they are predominately carbonate and bicarbonate rather than a chloride type.

Some RAISON concentration maps show several distinct patterns which clearly reflect Yukon geology. Cadmium, zinc, nickel, aluminium and cobalt reflect distinctly mineralized areas in the Selwyn Basin. The highest concentrations of zinc are in the Selwyn Basin, and low values are associated with deposits in the south-central Yukon.

Several variables, including magnesium, alkalinity, sulphate, hardness, calcium and specific conductance, reflect the general surficial geology of the Yukon. Low concentrations of filterable residues are found in areas of scattered permafrost and the highest concentrations are found in areas of continuous permafrost. Sodium and potassium concentrations are lowest in the southeastern portion of the Yukon. Copper, manganese, molybdenum, strontium, silica and pH show patterns that appear to have no relation to geology; but, for these variables, adjacent watersheds have similar properties. High concentration areas are associated with the cataclastic complex and the crystalline terrane. Low values are associated with the Mackenzie Platform.

## **DISCUSSION**

Three general patterns of water chemistry were observed. The first reflects the geology of the Yukon. Iron and calcium are typical of variables that are distributed in a fashion which suggests that the chemistry of the parent material is the controlling factor.

The second pattern was observed for filterable residues and variables such as sodium and potassium. This pattern closely resembles the distribution of permafrost in the Yukon. Permafrost has a significant impact on low-flows (Janowicz, 1990). These variables are suggested to be controlled by the groundwater sources (Whitfield and Clark, 1992). Alignment between permafrost and groundwater controlled ions suggests a control other than the parent material.

The third pattern is not consistent with a geological one. At present, this appears to be a function of hydrologic character.

The relationship to geology exists for materials that are highly soluble and are available for dissolution. Two types of distributions appear to be controlled in this fashion. The first is where the parent material controls the rate of dissolution. The second is where the rate of erosion controls it. The third is where the distribution of some variables is similar to that of permafrost, rather than to a pattern of parent material.

The results presented here are preliminary. During the winter of 1993, additional samples were collected from a number of streams. The samples were selected to meet three distinct needs: to fill in some of the data gaps, particularly in the south-east Yukon; to confirm some of the extreme values observed during 1992; and to confirm the observations.

## **CONCLUSIONS**

Data collected during the winter baseflow period are useful in establishing the relationship between stream chemistry and parent geology of source streams. Removing hydrologic variation by sampling only the winter stream flow is a useful method for isolating the controls on water chemistry. Three factors appear to control patterns of chemistry in winter baseflow: the parent material, the rate of erosion, and hydrologic conditions. Spatial variations and similarities indicate that many of the chemical variables observed are controlled by the bedrock geology. Some variables appear to be controlled by specific mineralized areas. Other variables reflect the pattern of permafrost distributions.

## **ACKNOWLEDGMENTS**

Field support was provided by Andrea Ran, Russ Gregory, Stuart Hamilton, Rob Mathewson, Tom Arsenault and Garth Norris. Susan Rowntree developed the RAISON applications for this study. Dr. Rory Leith modeled streamflow.

## **PUBLICATIONS AND REPORTS GENERATED**

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## **2.11 CURRENT CONTAMINANT DEPOSITION MEASUREMENTS IN ARCTIC PRECIPITATION (SNOW)<sup>1</sup>**

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### **PROJECT OBJECTIVE**

To quantify the snowfall deposition of persistent toxic chemicals in the Arctic and to assess the relative importance of this mechanism to the overall input of these chemicals to the region.

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<sup>1</sup>Editors' Note: This project is also funded under the AES Northern Contaminants Program. This summary also appears in Environmental Studies No. 72. Synopsis of Research Conducted Under the Northern Contaminants Program.

## PROJECT BACKGROUND AND DESCRIPTION

Atmospheric inputs to aquatic systems not in the Arctic have been identified as a major means of introducing persistent organochlorine pesticides and industrial compounds to those systems. The chemicals of interest are persistent and semi-volatile and undergo a repeated process of deposition and re-volatilization from water and land surfaces with a slow northerly movement. For such pollutants, the Arctic and Antarctic regions are considered to be the ultimate repositories.

Wet precipitation (rain and snow) is considered a major mechanism whereby the chemicals are transferred from the atmosphere to aquatic or terrestrial surfaces. In southern regions that are largely without anthropogenic influence, wetfall accounts for 90-100% of the chemical input to aquatic systems. In the Arctic, snowfall accounts for the majority of the wetfall (1991, 1992: 38, 59 % for Whitehorse, 51, 60 % for Baker Lake, 85, 89 % for Alert). Earlier work by Gregor *et al.* indicated that accumulated snow contained the target compounds at sub nanogram/litre levels in the snowmelt. These levels, if extended to all snowfall, would indicate annual loadings of 0.02-1  $\mu\text{g}/\text{m}^2/\text{year}$  - levels on the average to low level for the Great Lakes. All of this material does not necessarily become incorporated into the aquatic or terrestrial systems into which it is deposited. Evidence is available to show that losses from accumulated snow are significant for some toxic chemicals although it is noted that this only makes it available for deposition elsewhere.

The purpose of the overall study is to determine the levels of OC pesticides, PCBs and chlorobenzenes in Arctic snow. Determination of these analytes in accumulated snow was undertaken following the winter of 1991-92; large snow collectors were also employed at Whitehorse and Eureka to determine snow concentrations there on a weekly basis. During the winter of 1992-93, large snow collectors were established at two additional Yukon sites and at two sites in the Northwest Territories. Bulk samples were also collected at a number of sites during March 1993 in order to obtain a second synoptic survey of deposition patterns and to compare accumulated results with those that could be calculated using the weekly levels. In the

reporting year, covering the 1993-94 winter, a total of four weekly samplers were operated in the Yukon and five in the NWT. The present report describes some of the results for the sampling period 1991-93 and the collections from 1993-94. The Yukon samples were collected and funded under another project (M. Palmer, this volume) but are presented here for completeness.

## ACTIVITIES IN 1994

Samples were collected from the sites noted in Table 1. November to March weekly and accumulated snow (to March) samples have been extracted with dichloromethane using Goulden extractors at either Whitehorse or Resolute Bay. Additional weekly samples between March and May from the same locations are in process of extraction. All samples will be further processed and analysed at the NWRI laboratories.

**Table 1. Snow Sampling Locations for Winter 1993-94.**

Dawson, YT	Alert, NWT
Tagish, YT	Baker Lake, NWT
Whitehorse, YT	Cape Dorset, NWT
	Mould Bay, NWT
White Pass/Fraser, B.C.	Snare Rapids, NWT

Analysis of 1992-93 samples was completed during the reporting year; results for 1991-92 also became available. Most of the analytes occur at trace levels or are non-detectable in most samples. Their numbers, however, require some condensation for reporting purposes. The complete list is provided in Table 2. The atmospheric PCB congeners designated in the table are those which have been found to represent approximately 90% of the total PCB congeners in wetfall samples in the region of the Great Lakes. In the Arctic snow samples, these percentages are much less (60-75%), even in the weekly snow samples. This may reflect degradation on the way north; it may also be the result of losses, even from the weekly samples.

**Table 2. Analytes in the Snow Sampling Programme.**

OC Pesticide	Chlorobenzenes	PCB Congeners		
$\alpha$ - HCH	1,3-DCB	1	86	173
$\gamma$ - HCH (lindane)	1,4-DCB	5*	87*	180
Dieldrin	1,2-DCB	6*	101*	182
Heptachlor Epox.	1,3,5-TCB	7	103	183
$\alpha$ - Chlordane	1,2,4-TCB	8	105*	185
$\gamma$ - Chlordane	1,2,3-TCB	15	114	187
$\alpha$ - Endosulfan	1,2,3,4-TeCB	16*	118*	189
$\beta$ - Endosulfan	Penta-CB	17*	121	191
<i>p,p'</i> -DDT	HCB	18*	128	193
<i>p,p'</i> -DDD	1,2,3,5-TeCB	19	129	194
<i>p,p'</i> -DDE	1,2,4,5-TeCB	28*	137	195
<i>o,p'</i> -DDT		31*	138*	196
Heptachlor		32*	141	199
Methoxychlor		33*	143	200
Mirex		40	151	201
trans-Nonachlor		44*	153*	202
Heptachlor		45	154	203
Aldrin		49*	156	205
$\beta$ -HCH		52*	157	206
<i>o,p'</i> -DDD		54	159	207
		60*	170	208
		77*	171	209

\* Atmospheric congeners in the Great Lakes programme

## RESULTS

Data for two fluxes (and their corresponding concentrations) are noted in this report. Firstly, deposition at four weekly collection sites (three in the Yukon, one in the NWT), and secondly, accumulated snowfall at 21 NWT locations during winter 1991-92.

The analyte flux via the snow for a given period is:

$$\begin{aligned} F_{ij} &= C_{ij} \cdot V_i / A \\ &= C_{ij} \cdot P_i \end{aligned}$$

where "i" and "j" refer to an individual snowfall event or period, and to the chemical, respectively.  $C_{ij}$  (in ng/L) is concentration of "j" in the snowmelt and  $P_i$  (in mm) and  $V_i$  (in litres) refer to the amount and volume of precipitation expressed as water equivalent;  $A$  (in  $m^2$ ) is the area of the collector. If the units are as shown, the  $F_{ij}$  will be in  $ng/m^2$ .

For a protracted period, for instance the winter, the flux is the sum of the individual events or collection periods and can also be arrived at by using the volume weighted mean concentration ( $C_{vwj}$ ):

$$\begin{aligned} \Sigma F_{ij} &= \frac{\Sigma \{C_{ij} \cdot V_i\}}{\Sigma V_i} \cdot \Sigma P_i \\ &= C_{vwj} \cdot \Sigma P_i \end{aligned}$$

Assuming that a large fraction of the winter snowfall is covered and that the snow is sampled frequently enough that losses are not significant, this derived flux should be a good estimate of the flux via snowfall for the winter. Data on volume weighted concentrations and calculated fluxes based on these are presented in Table 3. For White Pass, the  $\Sigma P_i$  was not available and estimates have been made using the nearest site. It is noted that  $\Sigma P_i$  should be higher than shown for this site and that the flux should also be increased.

Snow accumulating on the ground does not reflect the target analytes in the falling snow due to several potential losses, for instance with runoff during periods of warming, degradation,

volatilization along with subliming snow, and drifting in and out of the collector. Some of these factors will be influenced by temperature and wind conditions. Experience in earlier studies by Gregor has shown that, collectively, these losses may amount to as much as 90% over a few months, depending on the analyte.

Estimation of the flux of the chemicals using the concentration in the accumulated snowfall late in the winter requires the depth of that accumulated snow plus the snow density, or alternatively, the area of the sampled snowpack. For the NWT sampling survey in March to May of 1992, data on snow density and depth were collected at the time of sampling. The available fluxes for the winter period can therefore be estimated using the observed concentrations in the snowmelt:

$$F_j = C_j \cdot 10 \cdot \rho_{\text{snow}} \cdot d_{\text{snow}}$$

where the " $\rho$ " is the snow density measured for the site at the time, and " $d$ " is the depth of the snowpack in cm; the flux will be in ng/m<sup>2</sup> for the specified units. The concentrations and fluxes so estimated are given in Table 4. While these fluxes might be available for release to the underlying ground water, there is no knowledge about what losses may have occurred between collection and final disappearance of the snow. There may also have been additional deposition from snow that fell subsequent to collection.

## DISCUSSION

At this stage of the study, the results presented in Tables 3 and 4 must be considered preliminary. There are concerns over whether the  $\Sigma P_i$  terms are representative of the quantity of snow that fell in the respective locations. Efforts will be made to determine whether these values are appropriate. It is also the intent of this study to compare the fluxes determined from accumulated snowpack and from weekly samples at the same locations. With these caveats in mind, the following observations are made.

From Table 3 (weekly collections) the most obvious feature is the high concentration (and correspondingly high fluxes) of  $\alpha$ -HCH and lindane at Eureka in the High Arctic. Comparison

Table 3. Concentrations and Fluxes at Weekly Snow Collection Sites.

	$\alpha$ -HCH		Lindane		$\Sigma$ -Chlordanes		DDT+DDE+DDD		HCB		$\Sigma$ PCBs	
	$C_{w/j}$	$\Sigma F_j$	$C_{w/j}$	$\Sigma F_j$	$C_{w/j}$	$\Sigma F_j$	$C_{w/j}$	$\Sigma F_j$	$C_{w/j}$	$\Sigma F_j$	$C_{w/j}$	$\Sigma F_j$
	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$
Fraser/White Pass, B.C. Winter 1992-93 P=186.6 mm*	0.84	0.16	0.30	0.06	1.0	0.19	0.75	0.14	0.25	0.05	22.	4.0
Tagish, YT Winter 1992-93 P=186.6 mm	0.54	0.10	0.19	0.04	0.72	0.13	0.13	0.02	0.18	0.03	17.	3.2
Whitehorse, YT Winter 1992-93 P=143.9 mm	0.31	0.05	0.08	0.01	0.38	0.05	0.03	<0.01	0.13	0.02	9.8	1.4
Eureka, NWT Winter 1992-93 P=39.0 mm	13.	0.52	6.8	0.26	0.12	<0.01	0.34	0.01	0.14	0.01	6.8	0.26

Precipitation (P) amounts are from the Atmospheric Environment Service. They represent the difference between total and rain precipitation for the entire winter period.

with the Yukon sites is not valid since they are far removed both in time and space. These levels have been checked and do not correspond to high blanks (all results in Tables 3 and 4 are blank corrected).

It is tempting to conclude that the geographic progression in the fluxes and concentrations of the analytes at the Yukon sites during the winter of 1992-93 is real. (A more realistic estimate of the amount of precipitation at White Pass would only accentuate the apparent trend). It is even more interesting to add Eureka to the list (excluding the HCHs) despite the year difference and lack of data at intervening locations. If the trend is real, a conclusion could be that there is a significant input to the area from the Pacific via this route.

In Table 4, data from the Hayes River sample seems anomalously high in fluxes for all analytes reported. This is primarily the consequence of a greater snowcover (i.e. d) at that particular location than was found at other locations. This highlights the difficulty in selecting an appropriate location (and snow depth) at each site. In order to arrive at a representative flux, it might be preferable to have fewer sites and more replications per site. Fluxes of  $\Sigma$ PCBs in samples from the Penny Ice Cap and Lady Melville Lake are also high with only modestly higher concentrations to explain the levels.

Even discounting the anomalies mentioned, the snow survey indicated a pattern of slightly higher fluxes in the eastern part of the study area. This is apparently the case for all of the reported compounds or classes except for the  $\Sigma$ PCBs. It should be noted that this does not include data for the Yukon region (except for the Peel River site) and an extension westward might change the apparent pattern if the input via the White Pass is real since it would differ from that of the 1991-92 survey.

## **DATA TREATMENT**

All data presented have been corrected for blanks determined using Milli-Q water extracted in the same manner as the samples and shown to be clean in the laboratory. Data also exists for

**Table 4. Concentrations and Fluxes from the NWT Snow Survey in 1991-92.**

# snow density & depth unavailable mean of three	$\alpha$ -HCH		Lindane		$\Sigma$ -Chlordanes		DDT+DDE+DDD		HCB		$\Sigma$ PCBs	
	C <sub>I</sub>	F <sub>J</sub>	C <sub>I</sub>	F <sub>J</sub>	C <sub>I</sub>	F <sub>J</sub>	C <sub>I</sub>	F <sub>J</sub>	C <sub>I</sub>	F <sub>J</sub>	C <sub>I</sub>	F <sub>J</sub>
	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$	ng/L	$\mu\text{g}/\text{m}^2$
Peel R. (YT) <sup>#</sup>	0.15		0.24		nd		nd		0.07		3.6	
Nahanni Butte	0.23	1.2	0.18	0.93	nd		0.03	0.18	0.24	1.3	2.1	11.
Great Bear L.	0.04	0.15	0.09	0.30	0.11	0.35	0.03	0.11	0.23	0.77	3.6	12.
Slave R.	0.04	0.10	0.05	0.11	nd		0.03	0.06	0.06	0.13	1.9	4.3
Ellice R.	0.21	0.69	0.22	0.74	nd		0.06	0.21	0.31	1.0	4.8	16.
Akasia R.	0.12	0.65	0.09	0.48	nd		0.03	0.15	0.16	0.87	1.9	11.
Reid L. <sup>*</sup>	0.08	0.38	0.11	0.48	0.02	0.11	0.02	0.08	0.13	0.60	3.4	15.
Kakisa R.	0.06	0.14	0.05	0.10	nd		0.02	0.05	0.26	0.57	4.2	9.2
Ft. Good Hope <sup>#</sup>	0.03		nd		0.05		0.07		0.06		1.9	
Baker/VOR L.	0.43	2.3	0.47	2.5	0.01	0.05	0.10	0.55	0.11	0.59	3.3	17.
Yathkyed L.	0.13	0.67	0.10	0.54	0.02	0.12	0.02	0.10	0.38	2.0	1.6	8.5
Hayes R.	2.4	33.	1.3	18.	0.09	1.2	0.14	2.0	0.18	2.5	3.6	50.
Back R.	0.02	0.11	nd		0.03	0.15	nd		0.20	1.2	0.9	5.3
Brown R.	0.34	1.4	0.46	2.0	0.03	0.13	0.10	0.43	0.25	1.1	3.1	13.
Thelon R.	0.26	1.3	0.24	1.2	nd		0.05	0.26	0.22	1.1	3.3	16.
Lorillard R.	0.09	0.22	0.12	0.29	nd		0.02	0.06	0.20	0.47	3.3	8.1
Seal Hole L.	0.44	2.8	0.26	1.6	0.11	0.67	0.04	0.23	0.13	0.81	2.2	14.
Stan.Fletch.L. <sup>*</sup>	0.92	3.4	0.95	3.4	0.14	0.50	0.39	1.4	0.04	0.15	6.7	24.
Chartand L. <sup>*</sup>	1.3	2.7	0.76	1.6	0.17	0.36	0.42	0.86	nd		9.0	19.
Ly Melville L. <sup>*</sup>	0.31	0.76	0.46	1.1	0.01	0.02	0.20	0.49	0.04	0.10	13.	31.
Penny Ice Cap	0.86	7.7	1.4	12.	nd		0.12	1.1	0.04	0.34	9.0	81.

each sample to correct the determined concentrations for recoveries of internal standards. This report does not include such adjustments since there is no agreement on whether this should be done or what limits should apply. For similar reasons, means and statistical comparisons have not been estimated because there is no agreement among the Northern Contaminants Program participants on how to deal with the question of non-detectables.

## **PROJECT COMPLETION**

At the 1994 meeting of the Northern Contaminants Program Technical Committee, it was decided that the weekly collectors at sites other than those co-located with air samplers of the Atmospheric Environment Service would be dismantled. Following the analyses of the samples each sample to correct the determined concentrations for recoveries of internal standards. The present report does not include such adjustments since there is no agreement on whether this should be done or collected in 1993-94 (Table 1), sampling in 1994-95 will be continued only at the Alert, Cape Dorset and Tagish sites. It is expected that 1995-96 activities will be limited to analysis of these samples as well as preparation of reports on the data developed.

## **ACKNOWLEDGEMENTS**

In addition to the regional persons who form part of the study team, this study is indebted to the numerous operators of the weekly snow samplers. Gratitude is also expressed to the Polar Continental Shelf Project at Resolute for provision of accommodation, facilities and transport without which the High Arctic part of the study could not have been undertaken.

### **3.0 COMMUNITY HEALTH ISSUES**

#### **3.1 TROUT LAKE WATER QUALITY STUDY**

##### **PROJECT COORDINATOR**

M. Swyripa  
Water Resources Division  
Indian and Northern Affairs Canada  
Yellowknife, NWT

##### **PROJECT OBJECTIVE**

To conduct an integrated multi-media monitoring study of water quality and fish within Trout Lake and the tributaries.

##### **DESCRIPTION**

The community of Trout Lake is located southwest of Yellowknife, near the provincial borders of British Columbia and Alberta (Figure 1). It forms part of the Trout River drainage basin that flows 375 km and drains an area of 13,170 km<sup>2</sup> (Allison and Nielson, 1981). The community is located on the southeast side of the lake and its residents follow a traditional lifestyle consisting of fishing, trapping and hunting.

Community drinking water is pumped directly from the lake into a tanker and batch chlorinated using sodium hypochlorite. The treated water is then delivered to the various homes and buildings. Wastewater and solid waste are collected and disposed of at the waste disposal site. In 1990, the waste disposal site was located along the winter road. The solid waste site was poorly maintained and located quite close to a small drainage system that flowed into the Island River that in turn flowed into Trout Lake (Swyripa, 1991).

Previously, the Mackenzie Regional Health Service identified water supply and dump site improvements as environmental health priorities for the community.

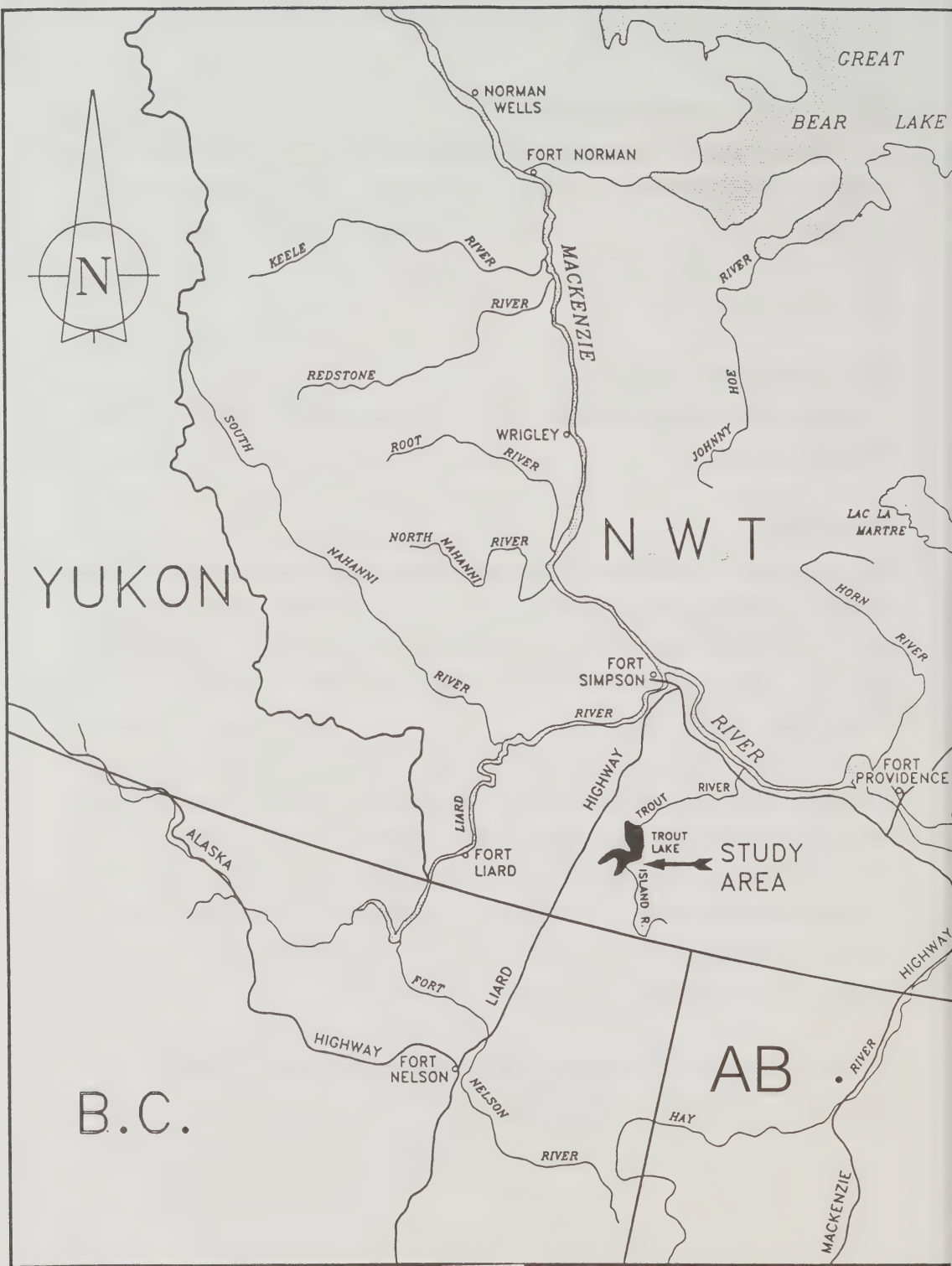


Figure 1 Location of Trout Lake Study Area.

In 1990, the Trout Lake Dene Band Council expressed concerns about the large number of dead fish floating in all areas of the lake between June and September 1989, and greater numbers of residents being treated for skin rashes. Residents wanted to know if the incidents were related to water quality problems.

Indian and Northern Affairs Canada, Fort Simpson District established a sampling program and a series of water samples were taken on three occasions in 1990. Water quality analysis included inorganic, physical and microbial parameters. To identify the possible sources of contamination to the lake, seven sampling stations were established. Results are outlined in Swyripa (1991).

Following this study, a more extensive multi-media sampling program was developed by Indian and Northern Affairs Canada, Yellowknife Office and the Department of Fisheries and Oceans in Yellowknife in 1992. With the assistance of the Trout Lake Dene Band Council, fish and water samples were collected and analyzed. Sampling was completed in 1992-93. The locations are shown in Figure 2.

## **RESULTS AND CONCLUSIONS**

### **Trout Lake Water Quality:**

Twenty biological and chemical parameters were measured on Trout Lake water. Water quality data was forwarded to Health Canada for a health risk evaluation. It was concluded that the water presented no risk to human health. It was recommended that all drinking water be properly treated before any human consumption. This recommendation is based on observed concentrations of total coliform and faecal coliform in lake water at a number of sites (Figures 3 and 4). Although levels of coliform bacteria in untreated water may exceed the Canadian Drinking Water Quality Guidelines (10 total coliform/100ml) at sites 1, 2, 3, 4, 9 and 14, levels such as these are not uncommon. Once treated by either batch chlorination or boiling, all coliform bacteria are destroyed.

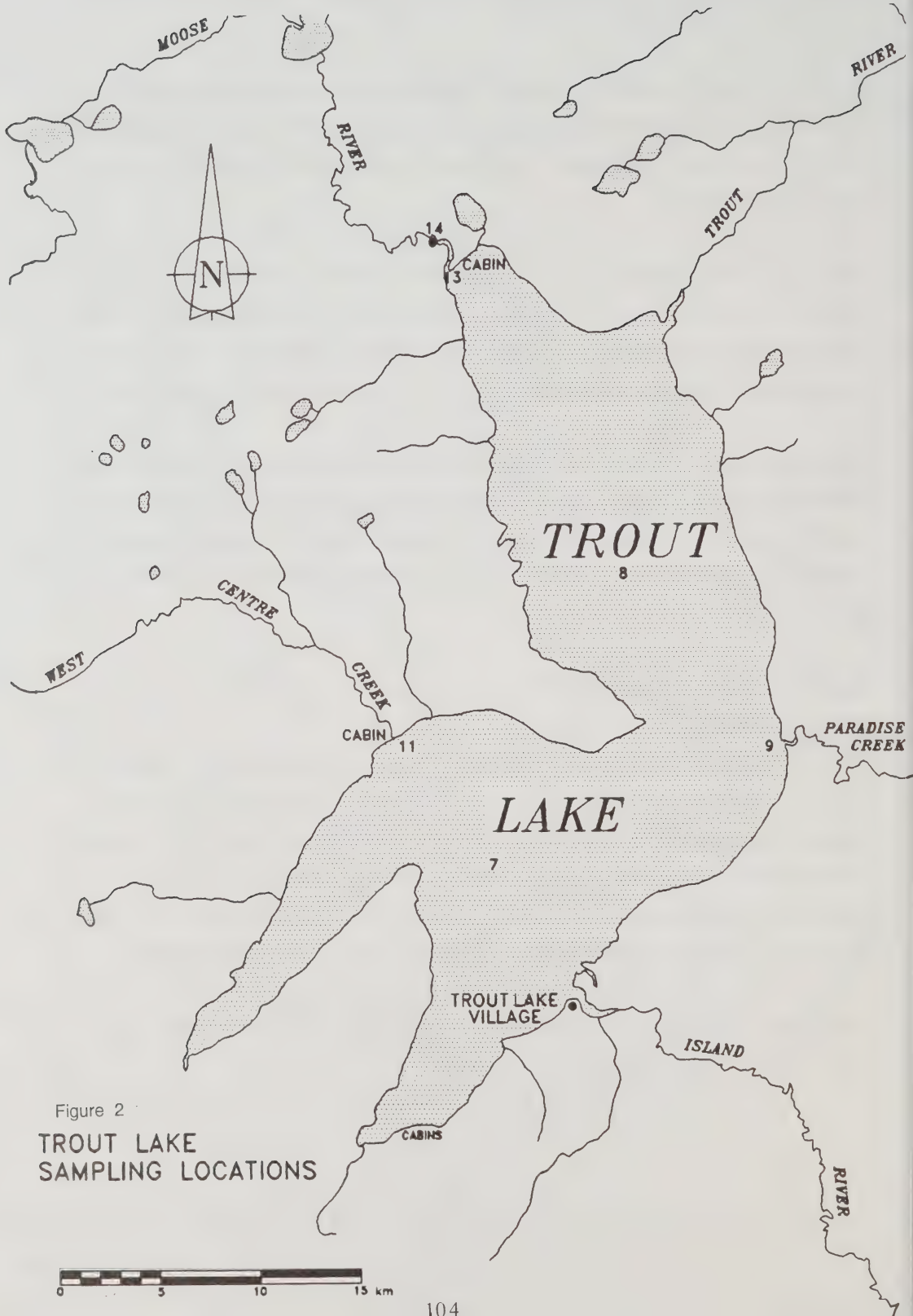


Figure 2  
TROUT LAKE  
SAMPLING LOCATIONS

# **TROUT LAKE WATER QUALITY STUDY** **FAECAL COLIFORM**

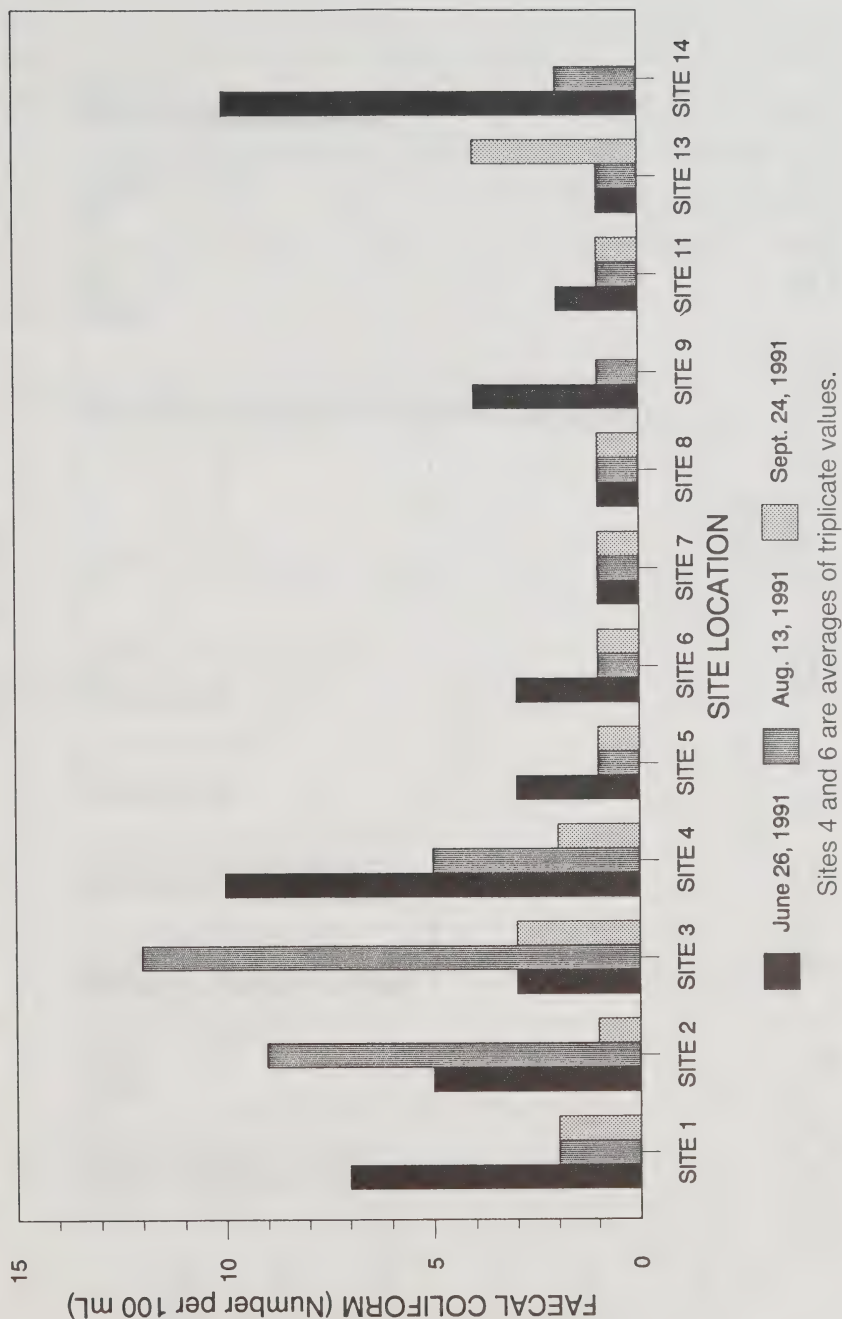
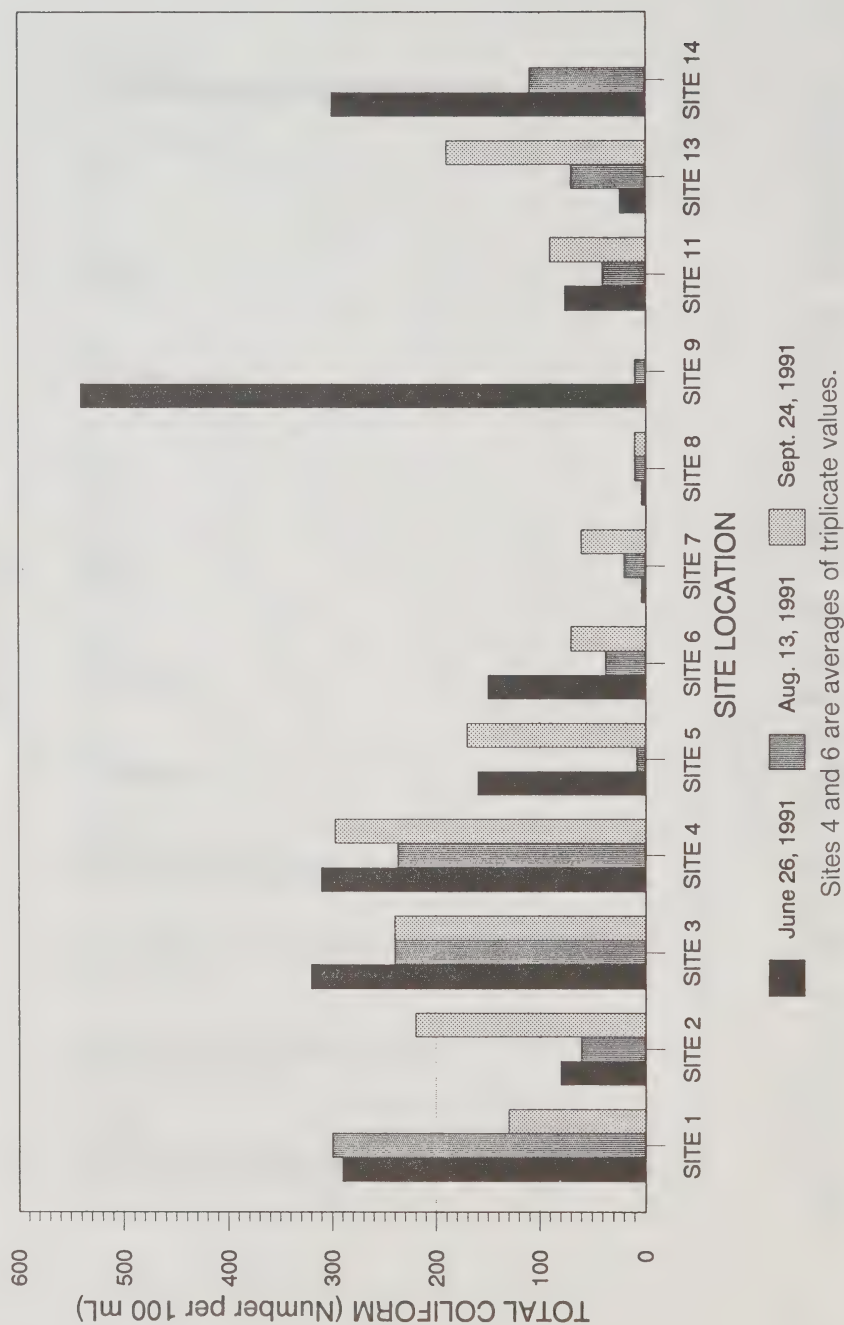


Figure 3

# **TROUT LAKE WATER QUALITY STUDY** **TOTAL COLIFORM**

Figure 4



### **Fish Analysis:**

Between March 1990 and July 1991, 85 fish were gill-netted and biological measurements such as length, weight, age and stage of maturity were recorded. Dorsal muscle samples were taken from 70 samples and analyzed for 28 trace metals. Trace metal analyses were conducted by Cantest Limited Laboratory in Vancouver, British Columbia. Detection limits (ppm wet weight) were as follows: 0.01 arsenic, 0.01 cadmium, 0.01 copper, 0.01 lead, 0.001 mercury, 0.05 nickel and 0.01 zinc.

A sub-sample of lake trout dorsal muscle and burbot liver was taken for organochlorine analysis. All organochlorine analyses were conducted at the Freshwater Institute, Winnipeg, Manitoba.

### **Biological Assessment:**

An assessment of fish health was made with the calculation of fish condition. The following formula was used:

$$K = (\text{weight} * 10^5) / \text{length}$$

Values suggest that walleye, longnose sucker, burbot and northern pike from Trout lake are in good condition.

### **Metal Analysis:**

Of 28 trace metals analyzed in fish dorsal muscle tissue, the following are summarized in Table 1: arsenic, cadmium, copper, lead, mercury, nickel and zinc. Although concentrations are not corrected for fish length, they are relatively low and can be considered typical of background levels in the area. Ranges and means are presented.

There are a few notable points related to data from Table 1. Firstly, cadmium and nickel concentrations were near or below detection limits. Secondly, all ranges of mercury concentrations for all species fell below the 0.05 ppm maximum limit for consumption. Given that mercury bioaccumulates, the levels reported (0.014 - 0.379 ppm) are relatively low.

TABLE 1. Heavy metal concentration (ppm wet weight) in the dorsal muscle of 6 fish species caught in Trout Lake in 1990 and 1991.

Species		Parameters							
		Moisture (%)	As	Cd	Cu	Pb (ppm)	Hg	Ni	Zn
NRPK	Max.	79.3	0.025	<0.05	0.85	0.022	0.127	<0.25	5.95
	Min.	79.1	0.018	<0.05	0.77	0.020	0.081	<0.25	5.18
	Mean	<b>79.2</b>	<b>0.022</b>	<b>&lt;0.05</b>	<b>0.81</b>	<b>0.021</b>	<b>0.104</b>	<b>&lt;0.25</b>	<b>5.57</b>
	SD	0.1	0.005	<0.05	0.06	0.001	0.033	<0.25	0.54
	N	2	2	2	2	2	2	2	2
	n	0	1	2	0	0	0	2	0
LKTR	Max.	82.7	0.025	<0.05	0.84	0.061	0.379	0.125	4.70
	Min.	72.5	0.011	<0.05	0.22	0.012	0.077	0.057	3.42
	Mean	<b>78.2</b>	<b>0.020</b>	<b>&lt;0.05</b>	<b>0.44</b>	<b>0.027</b>	<b>0.223</b>	<b>0.119</b>	<b>3.88</b>
	SD	3.1	0.005	<0.05	0.23	0.014	0.075	0.020	0.39
	N	12	12	12	12	12	12	12	12
	n	0	4	12	0	0	0	11	0
WALL	Max.	78.0	0.030	<0.05	0.70	0.305	0.233	0.125	5.04
	Min.	76.4	0.013	<0.05	0.19	0.014	0.028	0.078	4.09
	Mean	<b>77.3</b>	<b>0.024</b>	<b>&lt;0.05</b>	<b>0.33</b>	<b>0.038</b>	<b>0.133</b>	<b>0.119</b>	<b>4.51</b>
	SD	0.5	0.004	<0.05	0.14	0.063	0.048	0.015	0.28
	N	20	20	20	20	20	20	20	20
	n	0	13	20	0	11	0	17	0
LKWH	Max.	82.2	0.025	<0.05	0.66	0.067	0.033	<0.25	4.33
	Min.	78.1	0.011	<0.05	0.21	0.010	0.014	<0.25	3.35
	Mean	<b>79.7</b>	<b>0.021</b>	<b>&lt;0.05</b>	<b>0.35</b>	<b>0.029</b>	<b>0.026</b>	<b>&lt;0.25</b>	<b>3.79</b>
	SD	1.7	0.006	<0.05	0.15	0.021	0.007	<0.25	0.31
	N	7	7	7	7	7	7	7	7
	n	0	5	7	0	2	0	7	0
LNSC	Max.	83.3	0.021	<0.05	1.23	0.049	0.074	0.125	6.13
	Min.	77.4	0.012	<0.05	0.29	0.010	0.029	0.074	3.56
	Mean	<b>80.4</b>	<b>0.015</b>	<b>&lt;0.05</b>	<b>0.56</b>	<b>0.023</b>	<b>0.053</b>	<b>0.120</b>	<b>4.27</b>
	SD	1.2	0.004	<0.05	0.28	0.012	0.017	0.014	0.69
	N	16	16	16	16	16	16	16	16
	n	0	10	16	0	11	0	14	0
BRBT	Max.	81.9	0.027	0.025	0.70	0.038	0.181	0.125	8.04
	Min.	79.8	0.010	0.014	0.16	0.009	0.053	0.048	4.89
	Mean	<b>80.9</b>	<b>0.018</b>	<b>0.024</b>	<b>0.36</b>	<b>0.021</b>	<b>0.112</b>	<b>0.114</b>	<b>6.22</b>
	SD	0.6	0.005	0.003	0.19	0.008	0.041	0.026	0.94
	N	13	13	13	13	13	13	13	13
	n	0	0	12	0	2	0	11	0

Concentrations as high as 9 ppm have been observed in lake trout from Giauque Lake, a mercury-contaminated lake north of Yellowknife (Department of Fisheries and Oceans database).

Differences among species were also noted. Copper concentrations were highest in northern pike tissue (mean of 0.81 ppm, range of 0.77-0.85 ppm). Mercury concentrations were lowest in lake whitefish and longnose sucker (range of 0.104 - 0.223 ppm). And finally, zinc concentrations were highest in burbot tissue (mean of 6.22 ppm, range of 4.89 - 8.04 ppm).

Concentrations of measured organochlorines were relatively low (Table 2). All fish data were forwarded to Health Canada for health assessment. Concentrations of the measured organochlorines and trace metals in fish tissue did not present a health hazard to humans.

## CONCLUSIONS

Water quality results suggested that lake water and water in the tributaries are generally of good quality and well within the ranges recommended to support aquatic life. However, adequate treatment is still needed before human consumption or usage can be recommended.

The Government of the Northwest Territories (GNWT), recognizing the potential for contamination of the community's water supply from the old waste disposal site, has since established a new facility further away from any potential lake or river inlets. There is still concern about the community's water treatment and supply facilities. The GNWT recognizes these concerns and has been investigating alternative solutions.

All fish captured appeared healthy upon external examination; however, further laboratory testing should be done for a complete assessment. It is unlikely that the contaminants tested resulted in fish mortality. The 1989 fish mortality in Trout Lake was likely related to elevated water temperatures that year. These temperatures enabled two opportunistic waterborne pathogens *Aeromonas hydrophila* and *Pseudomonas putrefaciens* to infect fish. Fish kills were reported for many lakes of the Mackenzie River area during this summer, e.g. Kakisa Lake, Lac

TABLE 2. : Mean concentration (ng/g) of major organochlorines in fish from NWT lakes.

Lake/species/tissue	N	Lipid %	HCH	CHLOR	DDT	PCB	Toxaphene
<b>Burbot liver</b>							
Great Slave Lake	6	35.0±8.0	10.2±1.9	114±44.0	57.0±22.0	178±72.9	758±282
Trout Lake	6	40.3±12.1	13.7±4.7	33.3±12.2	19.8±7.2	50.1±9.7	152±65.9
<b>Lake Trout muscle</b>							
Trout Lake	9	4.2±1.9	2.5±2.6	10.5±10.3	5.3±4.7	13.8±9.0	44.0±55.0
Gordon Lake	6	3.0±1.3	0.68±0.34	7.9±6.3	5.4±5.0	16.3±12.6	35.7±36.8

La Martre (George Low, personal communication)).

The concentrations of trace metal and organochlorines in Trout Lake fish can be considered background levels. To keep concentrations of toxic substances low in fish tissue, it was recommended that efforts be made to prevent toxic substances (such as household detergents, paints, petroleum products, etc.) from entering the Trout Lake basin.

## **PUBLICATIONS AND REPORTS GENERATED**

Swyripa, M.W. 1991. Trout Lake Water Quality Study. Fort Simpson, NWT.

Swyripa, M.W. , C. Lafontaine and M.C. Paris. 1993. Water and Fish Quality from Trout Lake, NWT, 1990-91.

## **REFERENCES**

Allison, L. and W. Nielson. 1981. Sensitive Areas: Literature Review. WATDOC References, Mackenzie River Basin Study Report Supplement 1. Mackenzie River Basin Committee (Canada), 384 pp.

Health and Welfare Canada. 1978. The Guidelines for Canadian Drinking Water Quality. 1978.



### **3.2 GENE PROBE IDENTIFICATION OF *GIARDIA***

#### **PROJECT COORDINATOR**

P. Roach  
Water Resources Division  
Indian and Northern Affairs Canada  
Whitehorse, Yukon

#### **PROJECT OBJECTIVE**

To develop a genetic probe that will determine whether a *Giardia* cyst is of animal or human origin.

#### **DESCRIPTION**

*Giardia lamblia* is an intestinal protozoan parasite that occurs in humans and most warm-blooded animals. Infection is usually from cysts present in contaminated waters and can pass from human to human, or from animals to humans. Symptoms take from 10 to 15 days to appear and can vary from mild to severe intestinal problems with cramps and anorexia (CCREM, 1990). Health Canada has been conducting a *Giardia lamblia* research program for several years in locations across Canada. *Giardia* is often used as an indicator for water quality monitoring in the Yukon. AES funds were used to provide support to Health Canada's research into the genetic source-typing of *Giardia*.

When responding to community concerns, questions about the origin of *Giardia* are frequently asked. They are often about whether the cysts are of animal or human origin. This distinction is important since the presence of cysts of human origin establishes a possible source of human sewage to a body of water. However, if the cysts are of animal origin, their presence may be natural and not related to human activities.

#### **ACTIVITIES IN 1993/94**

A total of 614 samples were collected through the existing Health Canada survey. These samples were examined for the presence of *Giardia* cysts. Ten isolates were obtained from the total and

selected for genetic probe analysis.

## **RESULTS AND CONCLUSIONS**

Results are preliminary, however the hybrid gene probe demonstrated that the *Giardia* strains isolated from Yukon water samples were genetically similar to two internationally recognized strains of human infective *Giardia*. Some isolates (Yukon River samples from Carmacks and Whitehorse) demonstrated identical genetic grouping. This suggests that the strains could conceivably have originated from the same source. Although animals can act as intermediate hosts, evidence exists for human transmission. This finding is preliminary.

## **REFERENCE**

CCREM. 1990. Canadian Water Quality Guidelines.

### **3.3 WHITEHORSE SEWAGE DYE STUDY**

#### **PROJECT COORDINATOR**

P. Roach  
Water Resources Division  
Indian and Northern Affairs Canada  
Whitehorse, Yukon

#### **PROJECT OBJECTIVE**

To determine the efficiency of the Whitehorse sewage treatment facility by conducting a non-toxic fluorescein dye study of the sewage plume. This will determine whether the midstream diffuser is working adequately.

#### **PROJECT BACKGROUND AND DESCRIPTION**

The City of Whitehorse is located in south part of the Yukon Territory (Figure 1). The capital of Yukon has a population of 23,133 and is the largest city in the Territory. Municipal sewage treatment consists of a lift station that pumps sewage to a four-cell lagoon system. This system has a nominal retention time of six days and then discharges to the Yukon River, through a midstream diffuser. The diffuser mixes the sewage with water in the middle of the channel to ensure that high concentrations of sewage do not reach the shores for a distance downstream.

A new sewage system is planned for the City of Whitehorse and will consist of discharging the existing lagoon into a sixty-day retention lagoon system and then into a one-year retention lagoon. This proposed new system has brought into question the efficiency of the existing sewage system and diffuser. Public concerns focused on the potential downstream effects on the Yukon River of sewage discharge. The construction of a new system will require moving the existing diffuser; consequently, diffuser efficiency was evaluated. If necessary, a replacement diffuser will be installed.

The sewage plume was identified with the use of non-toxic fluorescein dye so researchers could identify the exact location of the treated effluent in the channel. The dye produces a green colour

# YUKON TERRITORY

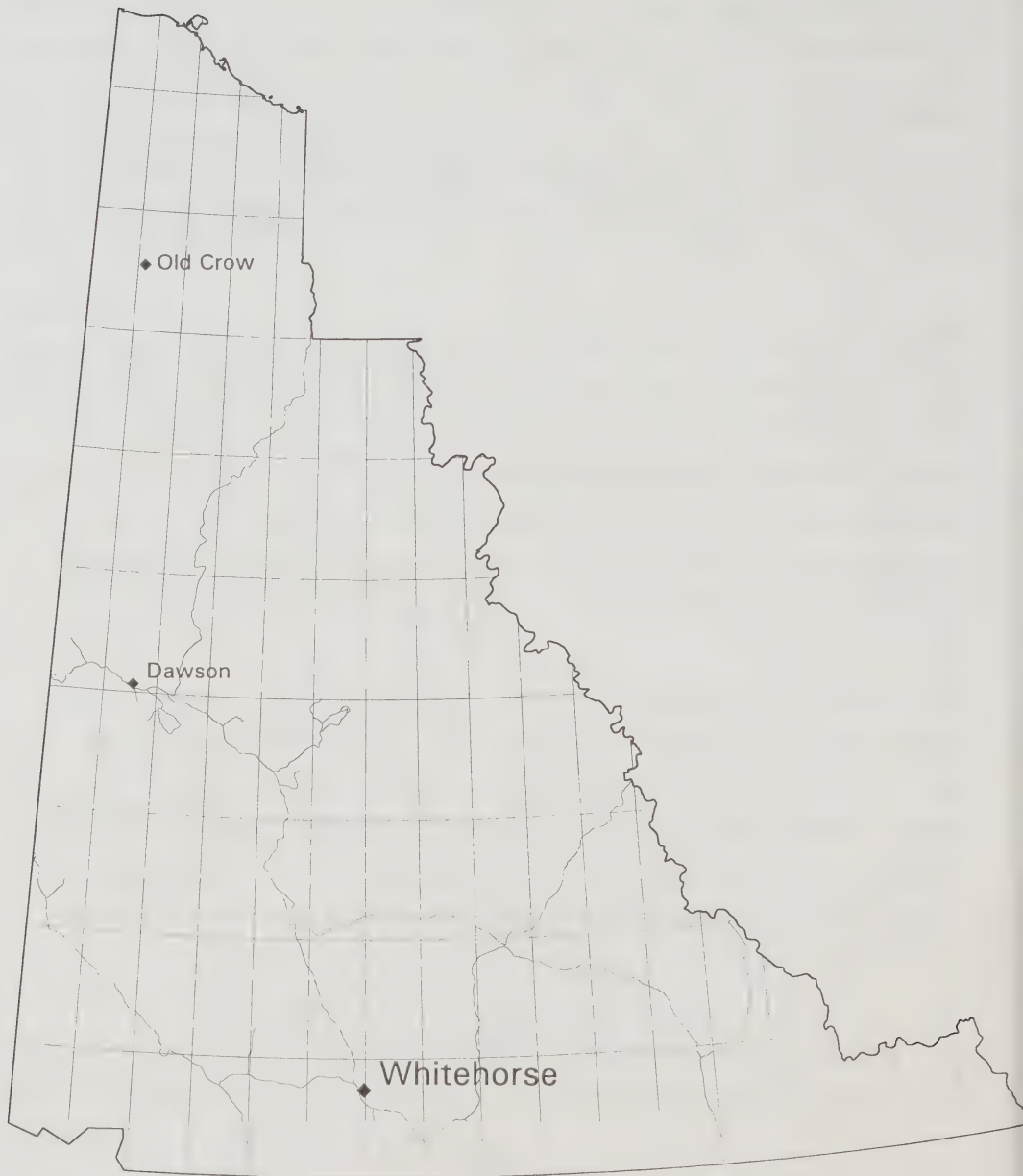


Figure 1 Location of the City of Whitehorse, Yukon.

and photo-degrades in 12 hours.

#### **Activities in 1993/94**

Fluorescein dye was added at the last discharge point of the lagoon system before the outfall diffuser in the River. A helicopter was used to produce video footage of the resulting dye plume for later analysis.

#### **RESULTS AND CONCLUSIONS**

The dye study showed that the sewage plume rises directly from the middle of the Yukon River and diffuses to both shores in less than one kilometre. This is considered extremely good performance for a diffuser and suggests that the existing design is suitable for use in the new system.

A video tape of the dye plume and observations was made available to the City of Whitehorse for evaluation and study by city engineers.

A composite tape of Whitehorse, Carmacks and Dawson dye plumes has been produced and made available to the public and government agencies.



### **3.4 KLUANE LAKE WATER QUALITY STUDY**

#### **PROJECT COORDINATOR**

P. Roach  
Water Resources Division  
Indian and Northern Affairs Canada  
Whitehorse, Yukon

#### **PROJECT OBJECTIVES**

1. To evaluate the efficiency of the Destruction Bay sewage lagoon; and
2. To evaluate the bacteriological condition of Burwash Landing community wells.

#### **DESCRIPTION**

Kluane Lake is located in the southwest corner of the Yukon Territory and is a headwater lake on the Donjek River system (Figure 1). With an area of 393 km<sup>3</sup> and a volume of 13 km<sup>2</sup>, it is the largest lake within the Yukon Territory. The communities of Burwash Landing and Destruction Bay, as well as the Arctic Institute, are located along the western shore.

The primary recreational use of the Lake is sport fishing, with lake whitefish and lake trout being popular species. Kluane First Nation operates a subsistence fishery on the Lake and outfitters support a small non-Native fishery. The lake serves as a source of drinking water, although there are two wells in Burwash Landing that provide potable water.

In 1990, a preliminary study conducted by the University of Calgary investigated point-source pollution to Kluane Lake. Several possible sources of sewage were identified and investigated. At the time, the Arctic Institute was identified as the only known contributor of sewage to Kluane Lake. The Institute is located a considerable distance upstream of Burwash Landing. It was suspected that other facilities, such as the Bayshore Motel, Destruction Bay sewage lagoon, Cottonwood Creek Campground and the Burwash Landing Resort also discharged sewage on an irregular basis, but no clear evidence was found.

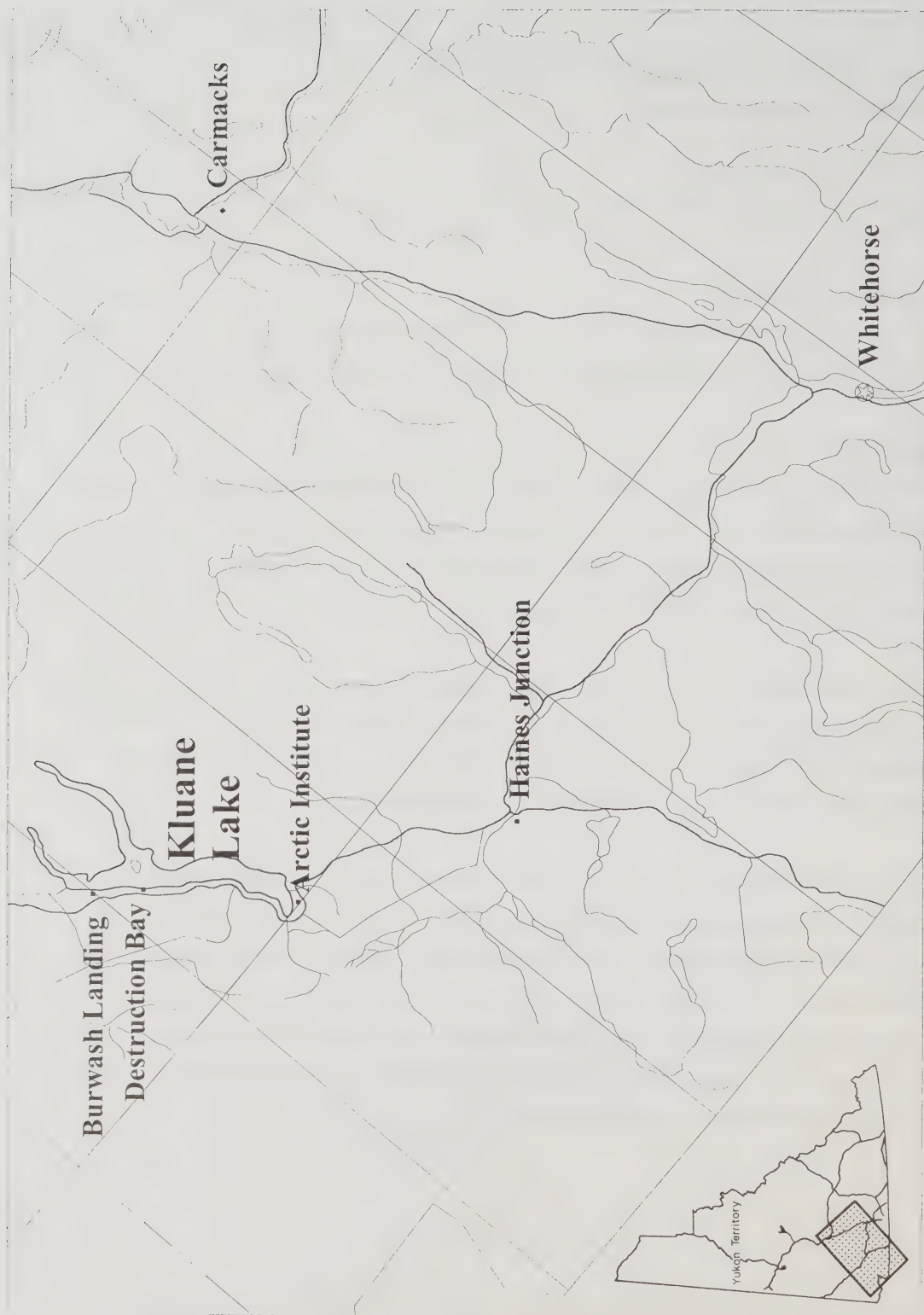


Figure 1 Location of Kluane Lake, Yukon

A meeting with the Kluane First Nation suggested that further work should be done to evaluate potential sources. This was in response to an incidence of gastrointestinal disease. Two water quality issues were identified:

### **Destruction Bay Sewage**

Kluane First Nation has been concerned for years about sewage discharge at the Destruction Bay sewage lagoon and the potential for sewage contamination from Burwash Resort. The Band is specifically concerned about potential effects on the water quality of Kluane Lake. The Destruction Bay sewage system receives sewage piped from Destruction Bay and sewage hauled from Burwash Landing as well as other establishments on the lake. Over the years, the lagoon has been modified to control annual discharge more effectively. In addition, original discharge points have been replaced.

### **ACTIVITIES IN 1993/94**

Kluane First Nation, Health Canada and the Yukon Territorial Government were contacted and a site investigation of the lagoon was done. The drainage channel to Kluane Lake and the sewage lagoon operation were also evaluated. Annual discharge was monitored and samples were collected for *Giardia* analysis.

### **RESULTS**

Monitoring of annual discharge showed that Destruction Bay sewage discharge was in fact not reaching Kluane Lake or the intervening wetland. Further results indicated that no *Giardia* cysts were present in the effluent. Bacterial levels were recorded at  $2.2 \times 10^3$  cfu (colony forming units). This concentration is well below the maximum concentration specified in the water licence for this site. It is unlikely that the lagoon, at its present size, could produce sufficient discharge to flood the lowland area and reach Kluane Lake.

A poorly designed septic system was discovered at the Burwash Resort. This system was releasing low concentrations of sewage into the lake. An eduction haul system was installed to

correct this and no other sources of contamination were detected.

### **Well Water in Burwash Landing**

Currently, the residents of Burwash Landing obtain drinking water from two wells located within the community. Water from the wells is distributed by a band-operated truck and disinfected with chlorine added directly to the water supply in the truck. Health Canada samples the existing wells regularly and has not detected contamination in either well.

### **ACTIVITIES IN 1993/94**

The community well was sampled by Health Canada. No evidence of microbial contamination was found.

### **RESULTS**

For all parameters measured the well water quality was within the standards set out by the Guidelines for Canadian Drinking Water Quality. Further investigation revealed that the incidence of gastrointestinal illness did not exceed that recorded in other parts of the Territory.

### **FUTURE DIRECTIONS**

There is currently no point-source pollution to Kluane Lake. All commercial and recreational operations on the lake have been evaluated by Indian and Northern Affairs Canada and Health Canada. The sites that previously discharged sewage to the lake have since installed other systems or modified their existing systems to eliminate any discharge of sewage. A report has been prepared and submitted to the Kluane First Nation. A meeting will be arranged for community members to discuss the findings of the report.

### **3.5 CARMACKS EXTENDED AERATION PLANT OPERATION/WESTERN COPPER PILOT PROJECT**

#### **PROJECT COORDINATOR**

P. Roach  
Water Resources Division  
Indian and Northern Affairs Canada  
Whitehorse, Yukon

#### **PROJECT OBJECTIVE**

To provide technical assistance to the Village of Carmacks on two water quality issues.

##### **1. Village of Carmacks Extended Aeration Sewage Plant**

The Village of Carmacks is located on the Yukon River north of the City of Whitehorse (Figure 1). In 1993, the village approached Water Resources Division, Whitehorse, to obtain assistance with water-related issues.

Municipal sewage in the village of Carmacks (population 487) is treated by an extended aeration plant that releases effluent into the Yukon River. This type of treatment consists of a four-stage system. First, the influent enters the plant after being screened to varying degrees. It is then mixed rapidly with air in the aeration tank and subsequently decanted to a clarifier where the floc formed through biological processes settles out. The floc is re-circulated to the aeration tank to maintain the biological population necessary for efficient sewage digestion. From the clarifier, the treated effluent moves to the discharge gallery, which consists of a set of baffles that remove any remaining floc before discharge from the plant. At Carmacks, the plant discharges to the Yukon River via a pipe located on the south bank of the river adjacent to the community.

The cold water of the Yukon River offers good conditions for the survival of *Giardia*. This protozoan is of particular concern because it is an intestinal parasite and can result in severe gastrointestinal problems in humans. Because of its potential to affect human health, *Giardia* was selected as an indicator of sewage treatment efficiency.

# YUKON TERRITORY

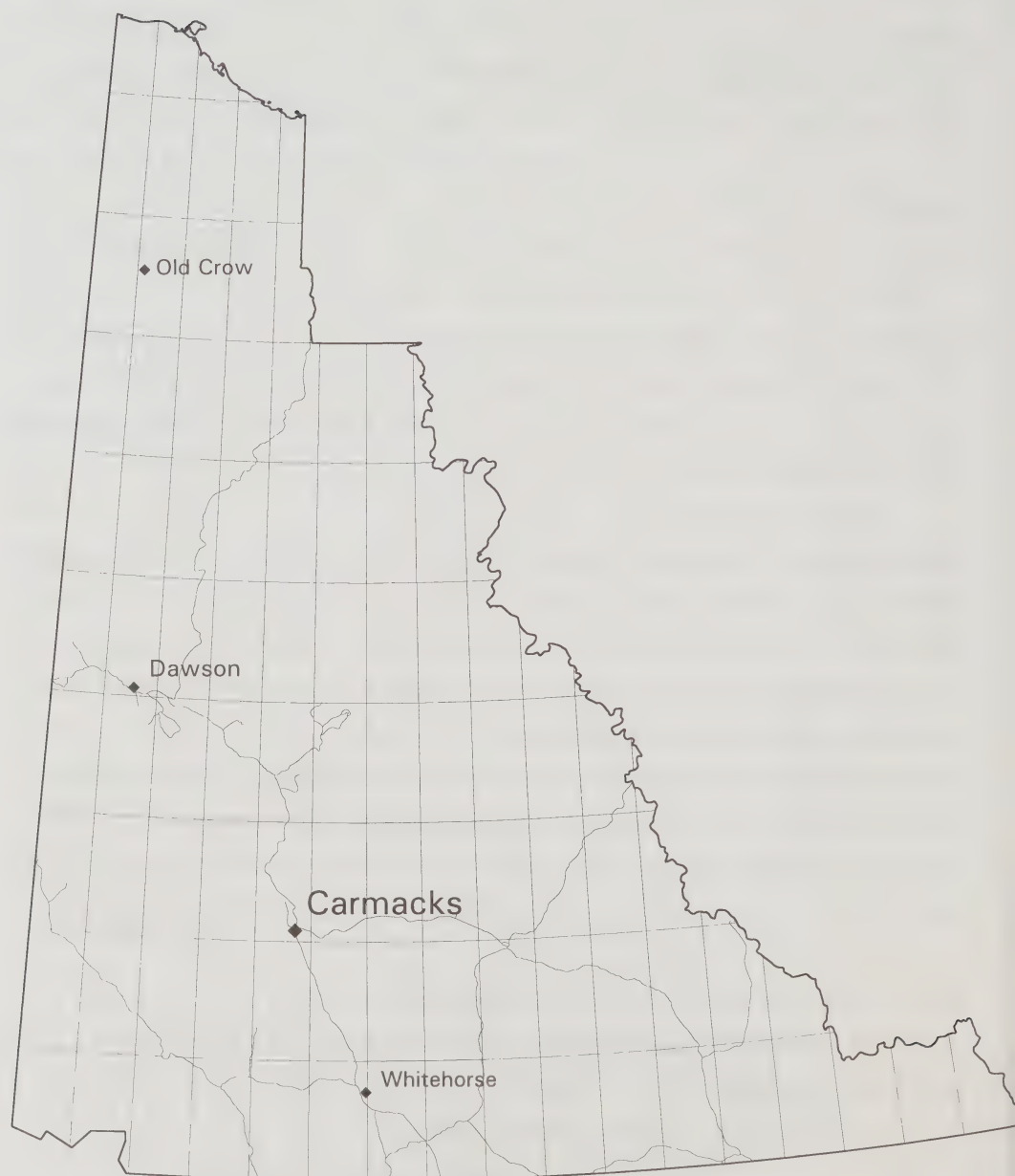


Figure 1 Location of the Village of Carmacks, Yukon.

The plant has been experiencing difficulties in meeting its water licence requirements for concentrations of suspended solids and bacteria.

**ACTIVITIES IN 1993/94**

Ongoing fluorescein dye studies identified the Carmacks sewage plume and dispersal. The sewage influent and effluent were sampled and *Giardia* concentrations were measured to assess removal efficiency. Twenty-four hour composite influent and effluent samples were collected from the plant.

**RESULTS**

**Table 1. *Giardia* Concentrations (Cysts/L) in influent and effluent from the village of Carmacks Treatment Plant in 1993.**

Date	Influent	Effluent
May 10 - 11	170	110
May 11 - 12	10	50
May 12 - 13	400	140
May 13 - 14	70	160

The data suggest that the plant occasionally received elevated concentrations of *Giardia* cysts. The variation observed in influent concentrations is however typical for *Giardia* concentrations in sewage. Effluent concentrations clearly show that the plant's removal efficiency is low.

**CONCLUSIONS AND FUTURE DIRECTIONS**

In the absence of equipment malfunctions, additional training was provided to the plant operator to improve efficiency in *Giardia* removal. Arrangements were made with the territorial government to ensure that this training would be provided. Following the study, the territorial

government initiated an investigation into the suitability and capacity of the existing plant. An extensive study will be conducted by engineering professionals to determine if plant capacity is adequate, or if the plant requires modification or replacements.

In addition, a fluorescence dye study will be conducted to determine the potential for impact on downstream river users. With the use of this nontoxic dye, the sewage plume can be mapped.

## **2. Western Copper Heap Leach Pilot Project**

The Western Copper Heap Leach Pilot Project consists of leaching copper from ore at a site near Carmacks. The use of acid heap leaching is new to the North and the pilot project was intended to examine the viability of this method in cold climates.

The principal problem for the community would be the disposal of waste solution after conclusion of the pilot project.

## **ACTIVITIES IN 1993/94**

The Village of Carmacks assisted in evaluating the use of an expanded sewage pit for the disposal of treated effluent from the pilot project leaching operation. The waste will consist primarily of water containing calcium sulphate (gypsum) in suspension and trace amounts of metals.

## **CONCLUSIONS AND FUTURE DIRECTIONS**

The community sewage pit was expanded to accommodate the residual solutions from the Western Copper Pilot Project. During the winter operation, project difficulties culminated in a spill. Fortunately this spill produced no discernible environmental impacts. However, the loss of solution negated the need for the expanded sewage pit.

### **3.6 EFFECTS AND CHARACTERISTICS OF DAWSON CITY SEWAGE DISCHARGE ON THE YUKON RIVER**

#### **PROJECT COORDINATOR**

P. Roach  
Water Resources Division  
Indian and Northern Affairs Canada  
Whitehorse, Yukon

#### **PROJECT OBJECTIVES**

1. To determine the concentrations of *Cryptosporidium*, *Giardia* and a number of viruses in the Yukon River downstream of the Dawson City sewage outfall; and
2. To determine the characteristics of the sewage plume using a non-toxic fluorescein dye to assess in the mixing patterns caused by Dawson City's sewage discharge method.

#### **DESCRIPTION**

Dawson City is located north of the City of Whitehorse in the centre of the Yukon Territory (Figure 1). The city has a population of 1,974 and is situated on the Yukon River which flows north from British Columbia and west through Alaska. Dawson City sewage is treated and released into the Yukon River. Recently, there have been concerns that the Dawson City sewage treatment system is not operating as expected.

Unacceptable concentrations of coliform bacteria were noted by effluent monitoring. More detailed analysis was warranted to determine the removal efficiency of the sewage treatment plant and mixing of the sewage plume. This study is timely because the City of Dawson is presently in the process of renewing its municipal water licence.

*Cryptosporidium*, *Giardia* and a number of viruses will be sampled. These organisms were selected because they have the greatest potential for long-term transport in a riverine system. *Giardia*, in particular, was selected because it is an intestinal parasite that can result in severe gastrointestinal problems in humans. Viruses are of interest because they cannot replicate

## YUKON TERRITORY

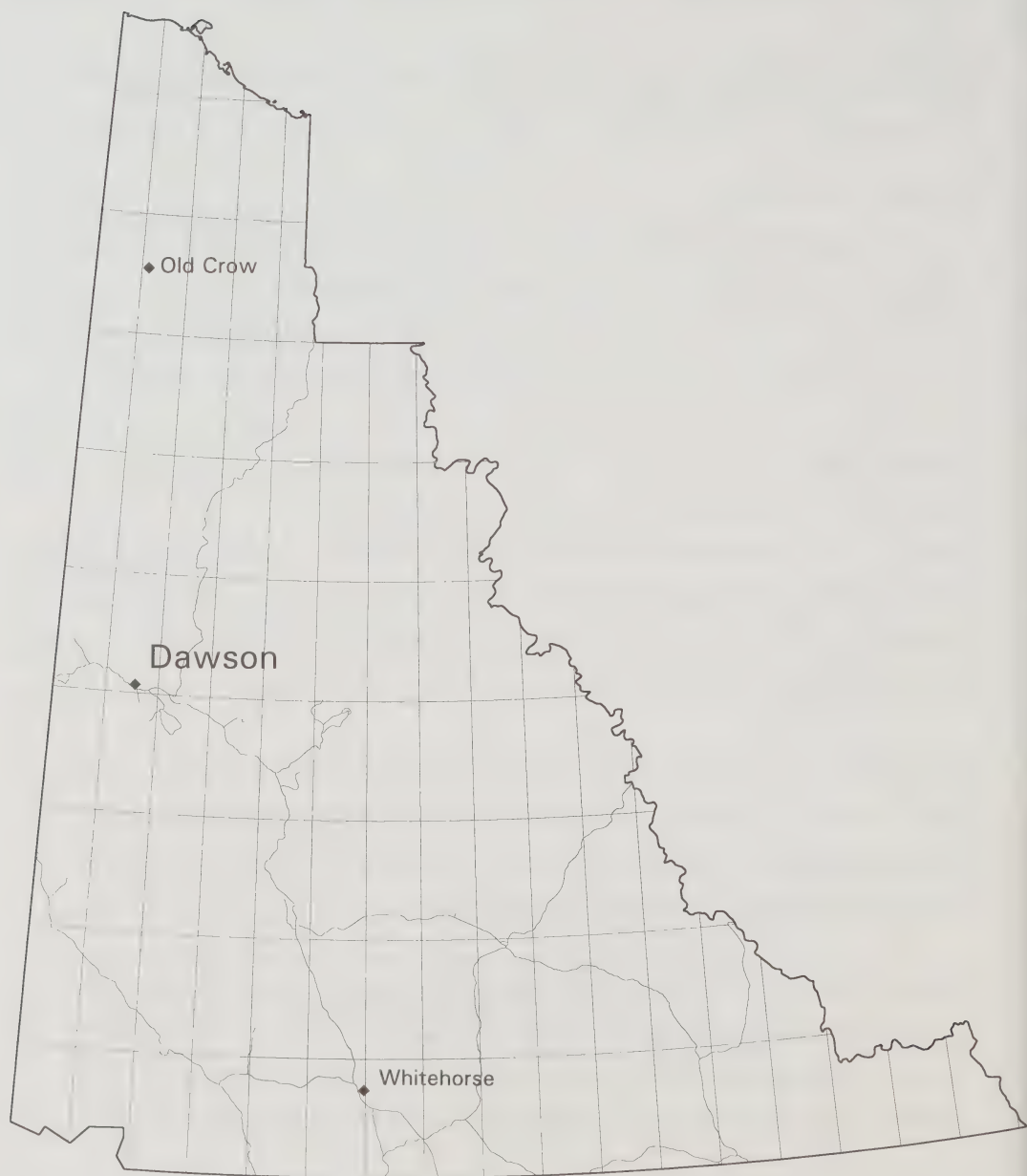


Figure 1 Location of the City of Dawson, Yukon.

outside their hosts. Further, viruses can occur at concentrations many orders of magnitude lower than coliform bacteria and can survive much longer than bacteria. Concentrations will be determined in water samples collected above and below Dawson City on the Yukon River.

To determine the exact path and mixing of the sewage plume, the plume will be tracked using non-toxic fluorescein dye. The dye photodegrades in 12 hours. Water samples will be taken in the plume and faecal coliform concentrations will be measured. Coliform were selected in this part of the analysis because river conditions in open water season do not permit the sampling of *Giardia* or viruses. The latter require a stable platform at the point of sampling. River conditions during the open water season will not allow this.

#### **ACTIVITIES IN 1993/94**

In March 1993, Yukon River water samples above and below Dawson City were collected through ice. Concentrations of *Cryptosporidium*, *Giardia* and viruses were determined. In addition, the viability of *Giardia* cysts was determined to serve as an indicator of the potential risk. These data were collected to support later sampling of the plume under open water conditions.

In June, an attempt was made to determine the path of the sewage plume using non-toxic dye inserted into the last discharge point of the system. The attempt met with little success due to high water conditions which resulted in heavy silt loads. Water samples were taken from the areas of the plume that could be identified and faecal coliform concentrations were determined.

In October, the dye study was repeated under lower flow conditions in the hope of improved results. The dyed plume was clearly visible and charted by a helicopter. During the video filming, samples were collected from the River under the direction of staff in the helicopter.

## RESULTS

### Dye Study:

The Dawson City sewage plume was observed to spread from a vertically mixing point source, surfacing just downstream (across from the Canadian Imperial Bank of Canada (CIBC)) of the discharge point. The narrow plume then travelled along the mixing zone between the Klondike and Yukon Rivers. The plume maintained a distance of approximately 100 metres from the bank until passing the ferry crossing where some mixing occurred in a back eddy.

### *Giardia* Concentrations:

Tables 1 and 2 illustrate the results of winter sampling above and below the City of Dawson. These results suggest that sampling locations were not near the sewage plume. This can be clearly observed in Table 1 where the concentrations of cysts in the raw effluent, even allowing for dilution, do not exceed background levels. This work clearly justifies the need to perform a dye study to ascertain the exact location of the sewage plume.

**Table 1. *Giardia* (Cysts/L) In Yukon River at Dawson. Sampling performed under ice conditions, March 1993.**

Date	Location	Concentration
March 23	ice bridge	24
March 23	above discharge	22
March 24	Klondike River	36
March 24	Yukon River	15
March 24	sewage effluent	50

**Table 2. Viral (organisms/L) in Yukon River at Dawson. Sampling performed under ice conditions, March 1993.**

Date	Location	Concentration
March 23	ice bridge	0
March 23	Yukon River	0
March 24	sewage effluent	141

Tables 3 and 4 indicate results of sampling performed in the sewage plume with the use of the non-toxic dye. These values varied considerably and likely reflected the variation in dilutions obtainable with sewage systems. The variation is a direct result of the short retention time at the plant. This produces a series of discharge slugs that vary in concentration as the influent changes from predominantly sewage to primary waste water, depending on the time of day. The samples (June and October) were not collected at the same time of day due to technical problems associated with the sampling.

**Table 3. Faecal coliform concentrations (100 mL) in Yukon River at Dawson, June 1993. Samples collected during unsuccessful dye study attempt.**

Date	Location	Concentration
June 1	ferry crossing	60
June 1	at Han fishery	74
June 1	above Han fishery	TNTC
June 1	at CIBC building	TNTC
June 1	at discharge	TNTC

TNTC= too numerous to count

The results of the October dye study (Table 4) suggest that the mixing zone requirements of the water licence are not being met. The dye study revealed that the discharge rises near the shore and proceeds to mix very slowly. The plume travels along the Dawson waterfront and continues as a contiguous flow until the dye could not be discerned in the water, approximately two kilometres below the discharge point. Further sampling, based upon the October dye study is planned for the following summer.

**Table 4. Faecal coliform concentrations (100 mL) in Yukon River at Dawson, October 1993. Samples obtained during dye study.**

Date	Location	Concentration
October 5	ferry crossing	25
October 5	Han fishery	20
October 5	above Han fishery	11
October 5	at CIBC building	16
October 5	at discharge	45
October 5	effluent	$2.4 \times 10^5$

## **4.0 SUSTAINABLE DEVELOPMENT ISSUES**

### **4.1 FORT RESOLUTION FISH MONITORING PROGRAM**

#### **PROJECT COORDINATOR**

J. Peddle  
Water Resources Division  
Indian and Northern Affairs Canada  
Yellowknife, NWT

W. Starling  
District Water Resources Officer  
Indian and Northern Affairs Canada,  
Fort Smith, NWT

#### **PROJECT OBJECTIVE**

To determine concentrations of arsenic, cadmium, copper, lead, mercury, nickel and zinc in fish tissue in the area around the abandoned Pine Point mining development near the community of Fort Resolution on Great Slave Lake.

#### **BACKGROUND AND DESCRIPTION**

Fort Resolution is located along the south shore of Great Slave Lake in the southwestern part of the Northwest Territories (Figure 1). It is a small town with a population of approximately 515 residents that rely heavily on Great Slave Lake fish resources.

The southern shore of Great Slave Lake is also the site of the abandoned Cominco Pine Point lead-zinc mine. The mine is approximately 60 km from the Town of Fort Resolution. This mine was in operation from November 1965 to April 1988. The wastewater from the operation was initially discharged into a nearby tailings pond and then flowed into a wetland adjacent to the site. This wetland eventually drains into Great Slave Lake.

During the 23 years that the mine was in operation, lead and zinc concentrations were measured in nearby waters at 16 locations surrounding the mine site. The wastewater was treated to meet



Figure 1 Location of Fort Resolution, Northwest Territories.

required water licence limits and metal concentrations were typically within recommended levels.

In 1992, residents of Fort Resolution expressed concern about possible detrimental effects of the mine on Great Slave Lake. Specific concerns focused on potential metal contamination of fish in Resolution Bay. Because residents consume fish caught in this area, they were concerned about detrimental effects on their health.

Water Resources Division, in conjunction with the Department of Fisheries and Oceans and local Fort Resolution residents, initiated a study to address the concerns.

### **Field Sampling:**

Five species of fish - walleye, lake whitefish, burbot, longnose sucker and northern pike - were collected from a site near Fort Resolution in October 1992. Biological data were collected including fork length, round weight, age, sex and maturity. Muscle tissue samples for all species and burbot liver tissues were analyzed for several trace metals. Burbot livers were analyzed separately because they contain a higher percentage of lipids than other tissues. Also, the liver is a detoxifying organ and a major site of deposition for toxic compounds.

Trace metal analyses were conducted by Cantest Ltd. Laboratory in Vancouver, BC. For details of methodology see the Fort Resolution Report (Peddle et al., 1995).

In 1993, additional sampling was conducted closer to the abandoned Pine Point mine, when residents indicated concerns about fish in areas closer to potential run-off. The additional sites were near the old Pine Point pumphouse and at Dawson Landing on Great Slave Lake. These sites were specifically selected because of their closer proximity to the potential mine outfall.

## RESULTS

### Fish Biological Data:

Table 1 shows the biological data collected on the Fort Resolution area fish. Fish condition was calculated using Fulton's condition factor:

$$K = W * 10^5 / L^3 \quad \text{where } L = \text{length (in millimetres) and } W = \text{weight (in grams)}$$

**Table 1. Biological descriptors and condition factor (K) for five fish species caught near Fort Resolution 1992-1993.**

Species		Length (mm)	Weight (g)	Age	K
Walleye	max.	539	1863	20	1.47
	min.	432	1061	8	1.12
	<b>mean</b>	<b>471</b>	<b>1396</b>	<b>11</b>	<b>1.33</b>
	sd	36	259	4	0.10
	n	9	9	9	9
Northern Pike	max.	835	4445	13	0.88
	min.	479	839	6	0.73
	<b>mean</b>	<b>666</b>	<b>2502</b>	<b>9</b>	<b>0.81</b>
	sd	89	922	2	0.04
	n	20	20	20	20
Lake Whitefish	max.	497	2422	16	2.08
	min.	365	625	9	1.24
	<b>mean</b>	<b>432</b>	<b>1356</b>	<b>13</b>	<b>1.64</b>
	sd	32	406	2	-
	n	20	20	20	20
Burbot	max.	841	3708	17	0.80
	min.	620	1585	9	0.59
	<b>mean</b>	<b>687</b>	<b>2252</b>	<b>13</b>	<b>0.69</b>
	sd	51	526	2	0.06
	n	21	21	21	21
Longnose Sucker	max.	534	2	20	1.54
	min.	427	28	10	1.20
	<b>mean</b>	<b>474</b>	<b>1511</b>	<b>13</b>	<b>1.41</b>
	sd	28	264	3	0.09
	n	13	13	13	13

max.=maximum, min.=minimum, sd=standard deviation, n=number of samples

The K values for sucker and burbot suggest that these species are in 'good' condition. Walleye, lake whitefish and northern pike are in 'very good' condition. Biological condition factors greater than 1.02 suggest excellent condition. Note that comparisons with fish conditions under different sampling conditions can be limited by factors such as net mesh size, etc.

### **Metal Concentrations in Fish Muscle Tissue:**

No formal data analysis has been conducted at this time; however, some preliminary observations can be made.

Trace metal concentrations in the fish muscle tissue are shown in Table 2. Because concentrations are not corrected for fish size, the range of metal concentrations is shown in addition to means. Cadmium and nickel levels were below detection limits of 0.01 and 0.05 ppm respectively and are thus not presented.

**Table 2. Range and mean of trace metal concentrations in ppm wet weight dorsal muscle tissue in five fish species collected at three sites. The abbreviation 'bd' indicates that concentrations are below detection limits. Data was converted to dry weight using the following calculation: dry weight X 1-%moisture/100= wet weight.**

	Copper	Lead	Mercury	Zinc
<b>Walleye (n=9)</b>	0.15-0.38 0.24	<0.01-0.02 <0.01	0.02-0.50 0.212	2.98-6.23 3.66
<b>Northern Pike (n=20)</b>	0.09-0.37 0.22	<0.02-0.03 <0.01	0.09-0.55 0.216	2.68-5.20 3.75
<b>Lake Whitefish (n=20)</b>	0.12-0.57 0.32	<0.01-0.11 0.02	0.01-0.26 0.047	2.28-3.39 2.78
<b>Burbot (n=21)</b>	0.16-0.56 0.28	<0.01-0.04 <0.01	0.07-0.17 0.117	2.79-4.87 3.54
<b>Longnose Sucker (n=13)</b>	0.31-1.08 0.56	<0.01-0.11 0.02	0.03-0.09 0.051	2.78-5.15 3.46
<b>Detection Limit</b>	0.01	0.01	0.001	0.01

Based on other data from Kam Lake, Trout Lake and Thistlethwaite Lake fish species, (Indian and Northern Affairs Canada, unpublished) the trace metal concentrations shown in Table 2 may be typical for the Great Slave Lake area and can be considered background levels.

Differences among fish species were noted. Notably, northern pike and walleye tissue had the highest mercury concentrations. This trend is often noted with piscivorous fish. Further statistical analysis of the data, following size corrections, may reveal other trends among species.

A Health Canada data assessment concluded that the metal concentrations would not pose a health hazard to consumers. This assessment considered all metal data in the various tissues for the five species.

### **Metal Concentrations in Burbot Liver Tissue**

Table 3 illustrates the concentrations of trace metals in burbot liver tissue. The data illustrate that some metals, notably copper and zinc, concentrate in this organ. This trend has been observed before. Although the two trace metals are essential to biological systems, they can be toxic in higher concentrations. Liver metal concentrations can be compared to concentrations in other fish species from Kam and Thistlethwaite Lake (INAC, unpublished).

**Table 3. Range and mean concentration of trace metals in burbot liver tissue in ppm wet weight. Means are based on sample size of 10. The abbreviation "bd" indicates concentration below or at the detection limit.**

	Copper	Mercury	Lead	Zinc
Burbot Liver	1.62- 9.96 5.98	0.011-0.050 0.020	<0.01	11.40-25.60 16.22

## **CONCLUSIONS AND FUTURE DIRECTIONS**

Concentrations of trace metals in fish tissue can be of major concern, particularly if fish serve as a source of traditional food. The data derived from this work were forwarded to Health Canada for health assessment. Based on detailed analysis, Health Canada concluded that no health precautions were required.

## **REPORTS AND PUBLICATIONS GENERATED**

Peddle, J. and C. Lafontaine. 1995. Fort Resolution Fish Monitoring Study, 1992-93. Final Report.

Sellers, A. 1994. 1993 Fort Resolution Fish Study underway. Article prepared for publication by regional communication staff.



## **4.2 ACID ROCK DRAINAGE STUDY IN NORTHERN CLIMATES**

### **PROJECT COORDINATOR**

P. Roach  
Water Resources Division  
Indian and Northern Affairs Canada  
Whitehorse, Yukon

### **PROJECT OBJECTIVE**

To conduct a preliminary investigation into natural and anthropogenic acid rock drainage (ARD) conditions in the Yukon. This work will consist of measurements of physical and chemical characteristics of water and biofilm samples. The goal is to develop a model for ARD in the Yukon.

### **DESCRIPTION**

Acid Rock Drainage (ARD) is low pH discharge or flow, usually enriched in metals and sulphate, which is generated by the oxidation of sulphide minerals and the associated metal leaching (Kwong and Whitley, 1992). The ARD process liberates trace metals, such as zinc, which may be extremely toxic to aquatic organisms. Once liberated under the acidic conditions, trace metals become biologically available and thus bioconcentrate in the tissues of the resident aquatic biota. ARD can occur naturally, but is exacerbated by current mining processes. It has been cited as the largest single environmental problem facing the mining industry today (Filion and Ferguson, 1990 as cited in SRK 1992).

Little is known about the nature of ARD in northern conditions. One can only speculate on the potential effects of the northern climate and hydrologic regime on acid rock generation. To further understanding, a study is being conducted by Water Resources Division with the National Hydrology Research Institute and the University of Calgary. Two sites were originally selected for water and biofilm (that algal, fungal and microbial material which colonizes rock surfaces) analysis: one site with naturally occurring ARD conditions; and a second site exhibiting ARD due to mining activities.

**Study Areas:**

Dempster Highway Site: This site consists of an unnamed stream crossing the Dempster Highway at kilometre 181 (Figure 1). The site is located approximately halfway between the Village of Dawson and the Eagle Plains Highway Lodge. ARD is generated from the exposure of natural sulphite shales with the resulting stream pH varying between 2.7 and 4.5.

Keno/Elsa Site: This site, at the United Keno Hills Mines Limited minesite, is at the Silverking adit near Keno City where the mine adit discharges to a non-acid rock drainage stream. The site contained rock naturally high in zinc, cadmium and lead, as well as sulphide ores. This mine was in operation from 1947 to 1989.

**ACTIVITIES IN 1993/94**

Water, native rock and biofilm were sampled at several minesites, along the Dempster Highway and at several control sites. This survey was an attempt to locate suitable study sites. This preliminary study also served to refine sampling techniques and general methodology.

**PRELIMINARY RESULTS AND FUTURE DIRECTIONS**

Data have been collected; however, further analysis is pending. Additional sampling is planned for 1995. The Silverking adit sampling site will be replaced; substantial changes in water chemistry have taken place because the adit was reopened in the last year.

Other studies planned for 1995 include the placing of substrates for biofilm growth at the Dempster site. This site will be monitored for biofilm development and water chemistry over the open water season, approximately June through September. The rate of growth, biomass, and the attenuation of metal ions within the biofilm will be recorded. In addition, an attempt will be made to determine the biofilm structure using confocal laser microscopy. It is hoped that this will indicate whether the metal ions are being provided with bonding sites by the biofilm matrix metabolizing the ions, simply trapping metals that precipitate, or some combination of these. This information will aid in the development of an ARD model for the Yukon.

# YUKON TERRITORY

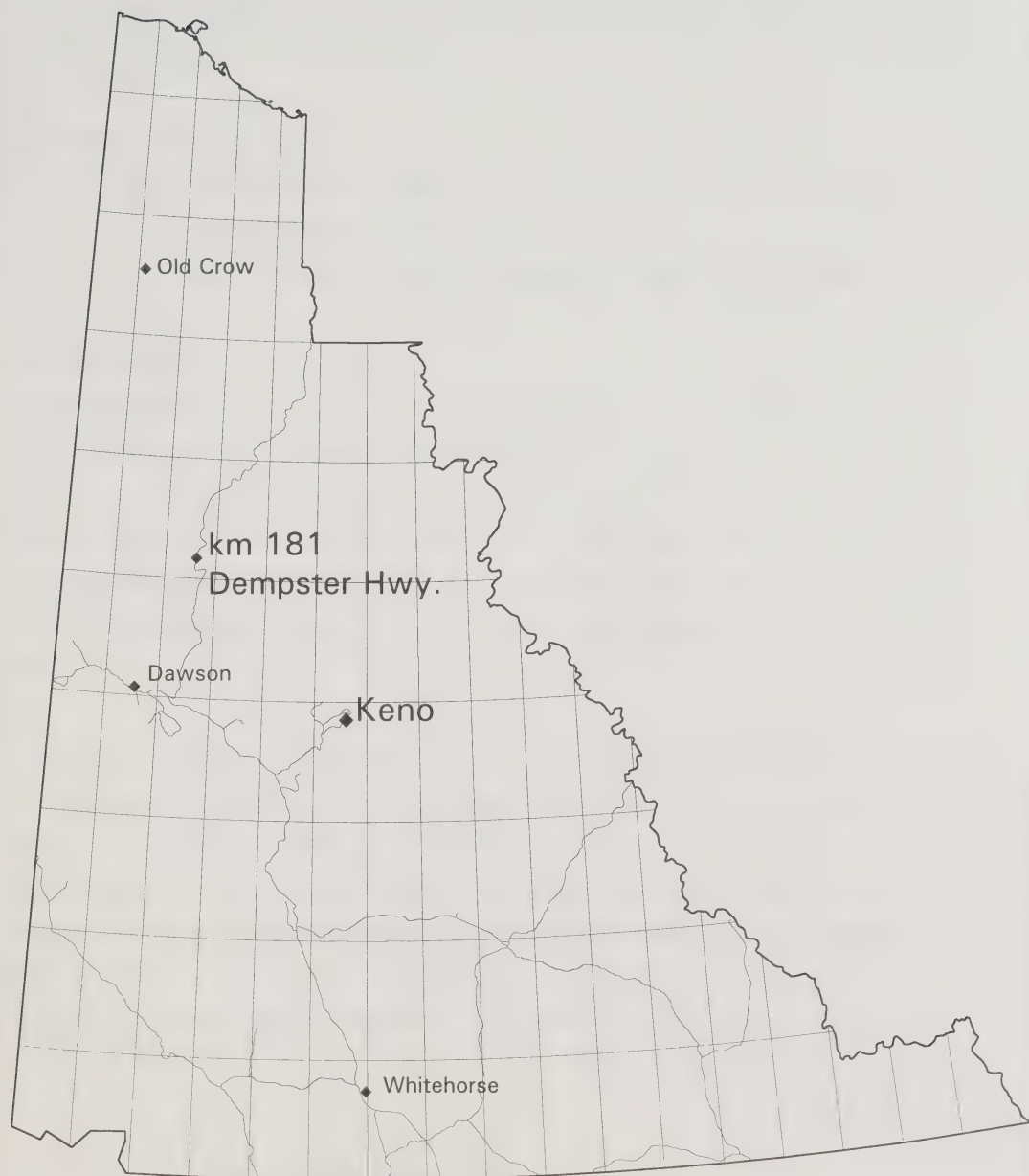


Figure 1 Location of study site at km 181  
and the United Keno Hills Mines Ltd. minesite

## REFERENCES

Kwong, J.Y.T. and W.G. Whitley. 1992. Heavy Metal Attenuation in Northern Drainage Systems. In: Proceedings of the 9th International Northern Research Basins Symposium/Workshop. Whitehorse, Yukon, 14-22 August, 1992. T.D. Prowse, C.S.L. Ommanney and K.E. Ulmer (Eds).

## **4.3 VENUS MINE TAILINGS STUDY**

### **PROJECT COORDINATOR**

P. Roach  
Water Resources Division  
Indian and Northern Affairs Canada  
Whitehorse, Yukon

### **PROJECT OBJECTIVES**

1. To determine concentrations of arsenic and other toxic metals in water, tailings and vegetation samples collected at the site; and
2. To assess the reclamation of the arsenic-contaminated Venus Mine tailings site.

### **DESCRIPTION**

The Venus Mine is located near the Windy Arm of Tagish Lake, south of Whitehorse, near the British Columbia border. The mine was in operation from 1908 to 1911 and 1970 to 1971. During these two periods gold, silver, lead and zinc were extracted. The ore containing the precious metals is predominantly arsenopyrite. While the native rock is carbonaceous and buffers any acid generation by the tailings, there is sufficient acid rock drainage action within the tailings for the continued release of arsenic to the water draining through the site and into Windy Arm.

Recently there has been growing concerns about the concentrations of arsenic in Windy Arm and the vegetation surrounding the site. These concerns were raised by the Carcross-Tagish First Nation. It is known, for example, that raspberries growing around the site are heavily contaminated with arsenic. This contamination has resulted from the deposition of wind-blown tailings material. Several studies have been conducted at the site over the years by the Water Resources Division of Indian and Northern Affairs Canada and the Environmental Protection Branch of Environment Canada to assess the nature and extent of the problem. This study, which

is conducted in conjunction with the AES Waste Program, builds on that research to answer some basic questions such as:

- are the tailings the only source of contaminants?
- what is the release mechanism for arsenic and other metals?
- will the metal release problem improve or get worse over time?
- what can be done to reduce the metal loading?

### **Sampling Program**

Initial sampling focused on surface water samples at a number of upstream, in-pond and downstream sites. Tailings, pore water and vegetation were also collected at various locations at the minesite. Metal concentrations were determined by ICP. Routinely monitored will be pH, conductivity and anion concentrations.

### **PRELIMINARY RESULTS**

**Surface Water** - Test results reveal that the pH of surface waters ranges from 7.6 to 8.3, while conductivity ranges from 480 to 900  $\mu\text{mhos/cm}$ . Initial results for sulphates reveal higher than background concentrations and that oxidation of sulphides or dissolution of sulphate salts is occurring. Alkalinity ranges from 100-200 mg/L.

Arsenic concentrations range from 0.005 mg/L in upstream samples to a high of 3.2 mg/L in a downstream seepage sample. Cadmium and lead were not detected in any sample. The highest reported zinc concentration was 0.13 mg/L at the downstream seepage site.

**Test Pits** - Based on detailed observations at the nine excavated test pits, extensive oxidation of tailings material is occurring with some pits showing oxidized layers up to 0.5 m thick.

**Vegetation** - Raspberries were collected at one site and analyzed for arsenic. Replicate samples show concentrations of 129 and 140  $\mu\text{g/g}$  respectively.

## **PRELIMINARY CONCLUSION**

A preliminary assessment of these findings suggests that the major sources of arsenic, both particulate and dissolved, are tailings, waste rock and natural rock. The rate of oxidation of unsaturated tailings material however, is controlled somewhat by the high alkalinity in the tailings pond. Oxidation and acid generation are the primary mechanisms that control metal release in the tailings pond.



## **4.4 SITE SPECIFIC EVAPORATION ESTIMATES IN THE NORTHWEST TERRITORIES**

### **PROJECT COORDINATOR**

B. Reid  
Water Resources Division  
Indian and Northern Affairs Canada  
Yellowknife, NWT

### **PROJECT OBJECTIVE**

To develop the instrumentation system and a working model for estimating evaporation rates at mine sites in northern Canada.

### **DESCRIPTION**

Evaporation studies are being conducted in conjunction with the University of Waterloo as part of a broad program of water balance investigations at mine sites. The overall goal of the program is to determine the long-term stability of tailing impoundments. Energy budget models, water balance methods and stable isotope techniques are used to comparatively estimate evaporative fluxes under northern conditions. The project aim is to verify the stable isotope method by comparing the results to other methods, such as direct pan measurements, lake water balances and model-derived values from meteorological data. The purpose of this study is

The design and operation of industrial projects requires climate data - such as precipitation, run-off and evaporation - to assess the efficacy of water containment structures such as tailings ponds. In many places in the Northwest Territories, climate data for these purposes are available only at locations some distance from the site. These data have relatively short cross-correlation distances in northern Canada (Gan, 1994) thus, interpolating climate data can result in erroneous or misleading conclusions in water balance calculations. On-site monitoring of meteorologic parameters during mining operations can provide useful data for tailings pond operation and for site abandonment decisions.

## Field program

During the summer of 1993, three automatic meteorology stations were installed and operated by Indian and Northern Affairs Canada, Water Resources staff. The stations were located at the Salmita-Tundra tailings pond (64°03'N, 111°11'W), at the Nanisivik Mines tailings pond (73°02'N, 84°33'W) and at Pocket Lake on the Giant Mine site near Yellowknife (62°30'N, 114°24'W) (Figure 1). Meteorological parameters recorded at the three sites were air temperature, relative humidity and wind speed at two levels, plus net solar radiation and precipitation. Thermistors were placed in the tailings pond for energy flux and heat storage measurements. Water levels were measured with electronic sensors. In addition, samples of pond water and rain water were collected at all three sites over the summer as part of a co-operative isotope-evaporation study being done with the University of Waterloo (Gibson, 1994; Gibson and Edwards, 1993).



**Figure 1. Location of automatic meteorology stations.**

The Salmita station was installed on May 12 prior to spring break-up. Ice movement on the lake damaged the station on June 26 but repairs were made on July 16 and the station operated until October 5. From analysis of air and water temperatures the end of the evaporation period was estimated to be September 28. The upper water temperature thermistor is several centimetres below the water surface; the date of freeze-up was therefore estimated as being one week prior to freezing temperatures at the upper thermistor. A total of 74 days of data were recorded at the Salmita site.

The Pocket Lake station was installed on July 8, 1993. The end of the evaporation period was established as October 7 when a thin ice cover was present on the lake. Data was recorded at Pocket Lake for a period of 90 days.

The station at Nanisivik was installed on May 28 and data were collected until November 16. The freeze up date was estimated to be September 25 using the same method as described above for the Salmita station. At the Nanisivik site data was recorded for 120 days.

### **Evaporation calculations**

Evaporation rates were calculated from the hourly meteorological data using the Penman Combination Method (Chow et al., 1988:90) and the Priestley-Taylor Method (Shuttleworth, 1992). Modifications were made to air and water density constants to reflect lower ambient temperatures in the study areas than those used in the reference examples (Brutsaert, 1982). A simple water balance method was also used to estimate evaporation rates. The evaporation estimate results are summarized in Table 1.

## **RESULTS**

Results from the Penman and Priestley-Taylor models were compared to determine the level of agreement between the two methods. The ratio between the Penman and Priestley-Taylor results are: Salmita=0.89; Pocket Lake=0.88; and Nanisivik= 0.92. The difference between the two methods appears small but the Priestley-Taylor Method is consistently higher than the Penman.

Water balances using changes in lake level and precipitation only were calculated for Salmita and Pocket Lake. This calculation was not possible for Nanisivik because of fluctuating pond water levels from mill operations. Because watersheds at the Salmita tailings pond and at Pocket Lake are small ( $< 5 \text{ km}^2$ ) and lakes cover about 90% of the basin area, surface inflows to the lakes were assumed to be minimal. Surface outflow at both sites is controlled by dams and zero outflow occurred during the study period. Ground water inflows and outflows at the two sites are minimal and assumed to be zero because of bedrock and permafrost.

**Table 1. Evaporation Model Results**

	Days of Record	Penman Daily Mean (mm/day)	Penman Cumulative (mm)	Priestly-Taylor Cumulative (mm)	Water Balance (mm)
Salmita	74	2.2	161	181	180
Pocket Lake*	90	2.4	218	248	163
Nanisivik	120	2.1	252	273	-

\* A Class A evaporation pan at Pocket Lake gave a value of 199 mm of evaporation over the observation period. The pan was allowed to go dry for isotope sampling, rather than maintaining the standard level.

A comparison of the Penman results with the water balance calculations gives ratios of 0.89 for Salmita and 1.34 for Pocket Lake. Likewise, a comparison of the Priestley-Taylor results and water balance calculations gives ratios of 1.01 for Salmita and 1.52 for Pocket Lake. As Table 1 shows, the modelled cumulative evaporation from Pocket Lake is much higher than the calculated water balance value. One possible explanation for this difference is that the assumption of zero inflow to Pocket Lake is incorrect. Approximately 110 mm of precipitation was received in the summer of 1993 and unaccounted overland flow into Pocket Lake would

result in an underestimation of evaporation by the water balance method. The water balance values compare quite favourably with the model outputs for the Salmita site.

The daily mean evaporation rates for the three sites ranged between 2.1-2.4 mm per day based on the Penman Combination model. A seasonal open water period was estimated by site observations made by DIAND staff and mine site personnel. By extending the daily mean over the estimated open water period, an annual evaporation rate was determined for each site (Table 2).

**Table 2. Estimated Annual Lake Evaporation Rates**

	Estimated Open Water Duration	Mean Daily Evaporation Rate	Annual Evaporation Rate
Salmita	100-110 days	2.2 mm	220 to 240 mm
Pocket Lake	130-140 days	2.4 mm	310 to 340 mm
Nanisivik	125 days	2.1 mm	260 mm

When compared to the mean annual lake evaporation map in the Hydrological Atlas of Canada (den Hartog and Ferguson, 1978), the extended annual evaporation estimates for Pocket Lake and Salmita are consistent with the map sheet values. The Pocket Lake site falls between the 300 and 400 mm isolines while the Salmita site lies between the 200 and 300 mm isolines. However, the Nanisivik site on north Baffin Island lies well below the 100 mm mean annual lake evaporation isoline. The modelled value of 260 mm at Nanisivik may be a factor of the physical characteristics of the study site. The Nanisivik station site is a small, shallow pond off the main tailings area. The small size and possible heat transfer from tailings deposition may affect the evaporation rate at the site. This will require further investigation.

## **CONCLUSIONS AND FUTURE DIRECTIONS**

The estimates of evaporation at Salmita using the Penman Method with the meteorologic data generally agree with the water balance data over the study period. A volumetric water balance calculation over the tailings area will provide a better comparison. Evaporation estimates (Penman Method) for Pocket Lake are higher than the on-site evaporation pan data due to the non-standard operation of the pan. Modelled evaporation results compared favourably with the corrected evaporation pan data from the Yellowknife Airport weather station located about 3 kilometres to the south.

Preliminary isotopic results at Nanisivik indicate that surface waters, including West Twin Lake, lose a substantial portion of water via evaporation. The measurable and systematic isotopic enrichment shows that quantitative determination of water balance using isotopic methods is clearly feasible.

## **PUBLICATIONS AND REPORTS GENERATED**

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## **4.5 PORT RADIUM ABANDONED MINE SITE MONITORING PROGRAM**

### **PROJECT COORDINATORS**

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### **PROJECT OBJECTIVE**

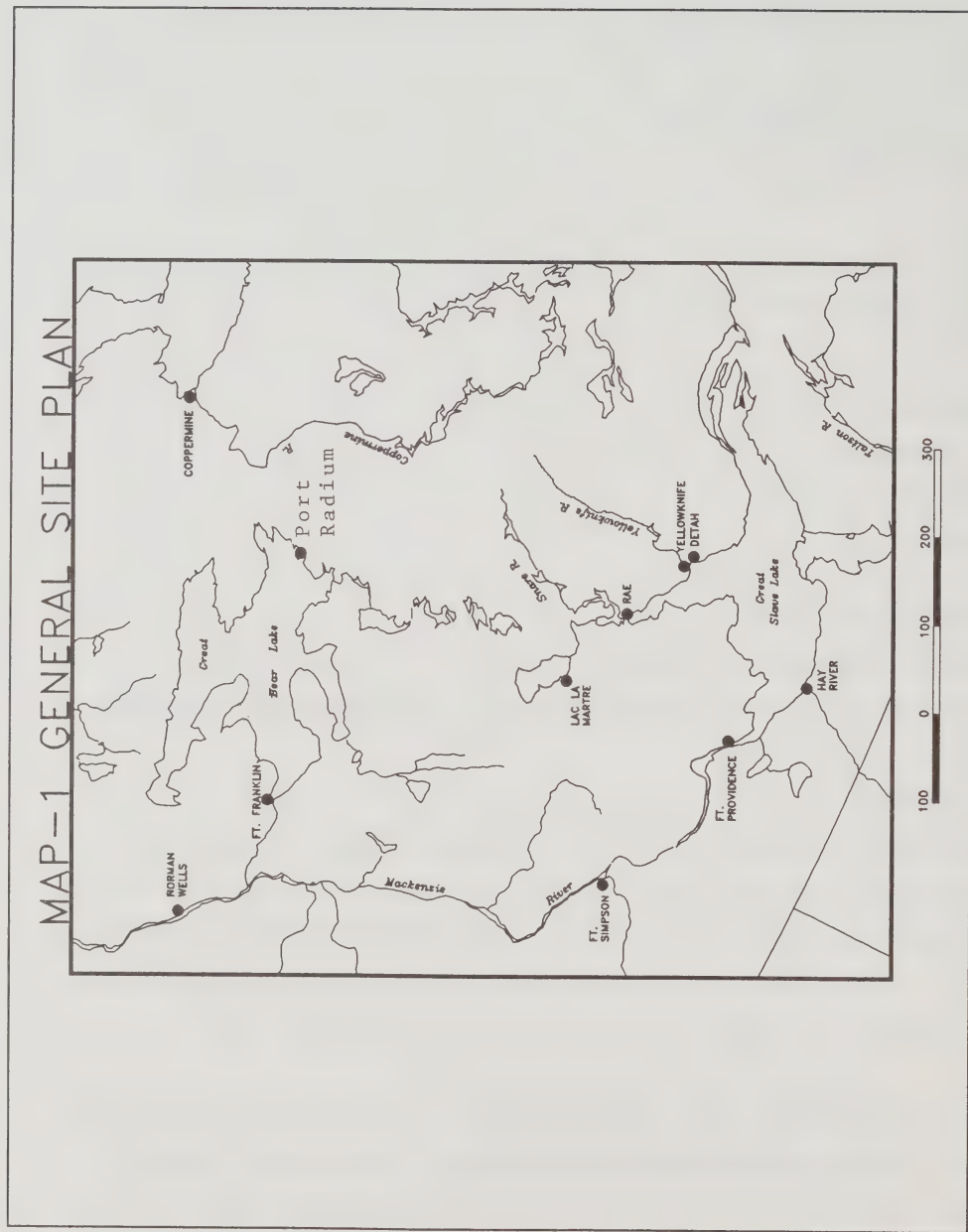
To conduct a monitoring program on the surrounding watersheds and fish species at the abandoned Port Radium mine site for possible trace metal and radionuclide contaminants.

### **DESCRIPTION**

The abandoned Port Radium uranium mine is located on a peninsula on the eastern shore of Great Bear Lake, Northwest Territories (NWT), midway along the McTavish Arm (Figure 1). The mine site covers an area from Murphy Bay, along the Cobalt Channel, to Labine Bay, to the northeast of Cobalt Island. The Port Radium mine was in operation from 1930 to 1960 and abandoned in 1982. Rayrock, a nearby uranium mine, was in operation from 1957 to 1959.

In 1981, the NWT Native Women's Association expressed concerns about the possible health effects of uranium tailings at the Port Radium mine site. In response to these concerns, the territorial Minister of Justice and Public Services directed that a review be undertaken to determine the possible health and environmental risks of uranium exploration and mining.

Figure 1 Location of Port Radium, Northwest Territories.



During May 1982, the initial meeting of the ad hoc Intergovernmental Committee on Environmental Contaminants (ICEC) was held and two working groups were established to address the Port Radium and Rayrock minesites. Indian and Northern Affairs Canada agreed to address the abandonment and restoration, and ongoing monitoring and Environment Canada (EC) agreed to address the leaching of radionuclides.

In 1982, EC awarded a contract to Dr. Margaret Kalin of the University of Toronto to examine the levels of radionuclides in sediment, water and macrophytes and to conduct preliminary leaching tests (Kalin,1982).

In 1985, ICEC assessed and made recommendations on a report prepared in 1985 by Hatfield Consultants. Four recommendations were made:

1. the West Adit tailings area should be reclaimed to minimize both acid generation and the mobilization of contaminants in surface water;
2. water levels and water quality of McDonough Lake and water quality of Bear Creek, Murphy Bay, Cobalt Channel, and Labine Bay should be monitored periodically;
3. the velocity, volumes and contaminant profiles of groundwater seeping from McDonough Lake should be measured; and
4. additional fish sampling should be carried out on Great Bear Lake to establish the levels of radioactive and nonradioactive contaminants.

#### **ACTIVITIES IN 1993/94**

A literature review was conducted and all concerns were consolidated regarding the abandonment of the Port Radium mine site. A water and fish sampling program was designed and implemented for McDonough Lake, Great Bear Lake and other surface waters surrounding

the mine site. In addition, sites used in previous investigations were sampled to identify changes in local conditions. The sampling program focused on those areas associated with past tailings deposition and drainage pathways. The four sampling areas were: Silver Point and Labine Bay, Murphy Creek discharge, Bear Creek and Bear Bay, and McDonough Lake and McDonough Creek.

## **Sampling**

### Water Quality Sampling

Water quality sampling consisted of surface and profile grabs. Basic parameters such as pH, conductivity, dissolved oxygen, salinity, temperature and turbidity were measured. Additional lake water samples will be analyzed for trace metals and a number of radionuclides including  $Pb_{210}$ ,  $Ra_{226}$  and Uranium. All physical and metal analysis will be conducted at the Northern Water Laboratory in Yellowknife, NWT. Radionuclide concentrations will be determined at the Saskatchewan Research Council Analytical Services Laboratory in Saskatoon, Saskatchewan.

### Fish Sampling

Fish sampling was conducted with the assistance of local residents and the Department of Fisheries and Oceans (DFO). Two main sampling areas were selected: the Port Radium minesite (specifically at the Murphy Creek outlet, Labine Bay, Silver Point and Bear Bay) and Deerpass Bay, an area used for domestic fishing (specifically at Scented Grass Hills). The latter site is a control site as well as an important fishing area for the residents of Fort Franklin.

Three fish species were collected: lake trout, lake whitefish and longnose sucker. These species were selected because they represent three distinct niches in the food chain. Fish analysis will include a number of trace metals as well as the radionuclides  $Pb_{210}$ ,  $Po_{210}$ ,  $Ra_{226}$  and Uranium. Trace metal analysis will be conducted by DFO Environmental Contaminants Laboratory in Winnipeg, Manitoba. Detection limits are shown in Table 1. Radionuclide analysis will be conducted by Saskatchewan Research Council Analytical Services Laboratory in Saskatoon, Saskatchewan.

**Table 1. Detection limits for metals analyzed in fish tissues.**

Metal		Detection Limits (ppm)	
		Liver	Muscle
Arsenic	As	0.06	0.05
Cadmium	Cd	0.0002	0.0001
Cobalt	Co	0.04	0.02
Copper	Cu	0.2	0.1
Lead	Pb	0.03	0.03
Mercury	Hg	0.003	0.003
Nickel	Ni	0.04	0.02
Selenium	Se	0.06	0.05
Zinc	Zn	0.04	0.02

## PRELIMINARY RESULTS

Results of water quality sampling and fish radionuclide analysis are pending.

Metal concentration data for fish tissues are available and are presented in Table 2. Muscle and liver tissues were analyzed for nine trace metals (As, Cd, Co, Cu, Pb, Hg, Ni, Se and Zn). All results above detection limits are reported in milligrams of element per wet kilogram (ppm) of tissue. Mean concentrations presented here are not corrected for fish size. Detailed data analysis is ongoing and the results are pending. In addition, Health Canada will be conducting a health assessment.

Although the assessment of fish health and the identification of potential health hazards is not possible at this time, it is possible to compare the metal concentrations found in fish from Great Bear Lake to concentrations in fish from other lakes in the Northwest Territories. The data were compared to data from Giaouque, Thistlethwaite and Kam lakes, which were all affected by

**Table 2.** Biological descriptors and metal concentrations (ppm wet weight) in the muscle and liver tissues of lake trout, lake whitefish and arctic grayling captured at Port Radium and Deeppass Bay in August 1993  
M: muscle; L: liver; N=total sample size below direction limit

Species	Location	Length mm	Weight g	Age years	K factor	Maturity * male female	Arsenic M L	Cadmium M L	Cobalt M L	Copper M L	Lead M L	Mercury M L	Nickel M L	Selenium M L	Zinc M L
Lake Trout		Max	667	38	1.55		0.22 0.38	0.0011 0.96	<0.02 <0.04	0.45 71.93	<0.03 0.09	0.197 0.263	0.176 0.131	0.42 3.72	4.33 128.39
		Min	435	13	1.07		<0.05 0.11	0.0002 0.018	<0.02 <0.04	0.24 5.04	<0.03 <0.03	0.027 0.028	<0.02 <0.04	0.17 0.81	2.81 26.11
	Port Radium	Mean	559	23	1.26	8 2	0.11 0.26	0.0005 0.29	<0.02 <0.04	0.31 22.31	<0.03 0.02	0.114 0.121	0.022 0.028	0.3 2.23	3.29 46.98
		S.D.	71	846	7	0.13	0.06 0.1	0.0002 0.275	0 0	0.06 18.07	0 0.02	0.052 0.069	0.044 0.03	0.06 0.85	0.42 25.09
		N	14	14	14	9(7) 5(3)	14 14 1	14 14 0	14 14 14	14 14 0	14 14 11	14 14 0	14 13 0	14 14 0	14 14 0
Lake Whitefish		Max	652	41	1.44		0.26 0.22	0.0005 0.188	<0.02 <0.04	0.33 17.53	<0.03 <0.03	0.239 0.309	0.416 0.43	0.31 2.8	3.1 42.34
		Min	421	867	1.16		0.05 0.06	<0.0001 0.032	<0.02 <0.04	0.24 5.75	<0.03 <0.03	0.119 0.095	<0.02 <0.04	0.21 1.05	2.68 22.56
	Deeppass Bay	Mean	551	2001	1.16	6,7,8 1,1-2,2,3	0.15 0.15	0.0002 0.058	<0.02 <0.04	0.26 10	<0.03 <0.03	0.182 0.172	0.062 0.088	0.26 1.79	2.84 29.93
		S.D.	56	616	0.06		0.07 0.05	0.0001 0.047	0 0	0.03 3.97	0 0	0.044 0.068	0.13 0.134	0.03 0.54	0.15 5.6
		N	10	10	10	6(2,2,2)4(1,1,1)	10 10 0	10 10 1	10 10 10	10 10 0	10 10 10	10 10 0	10 10 8	10 10 0	10 10 0
Arctic Grayling		Max	652	41	1.44		0.39 0.19	0.0009 0.075	<0.02 <0.04	0.27 19.24	<0.03 <0.03	0.112 0.361	0.12 <0.04	0.32 1.67	3.78 45.48
		Min	421	867	1.32		0.1 0.13	0.0002 0.03	<0.02 <0.04	0.2 3.2	<0.03 <0.03	0.039 0.059	<0.02 <0.04	0.26 1.12	2.95 27.16
	Deeppass Bay	Mean	505	1956	1.32	8 2	0.2 0.16	0.0004 0.046	<0.02 <0.04	0.24 10.53	<0.03 <0.03	0.068 0.148	0.038 <0.04	0.28 1.39	3.28 32.77
		S.D.	109	1455	0.13		0.13 0.03	0.0003 0.021	0 0	0.03 7.25	0 0	0.031 0.143	0.055 0	0.03 0.24	0.37 8.55
		N	4	4	4	3(2) 1(1)	4 4 0	4 4 0	4 4 4	4 4 0	4 4 4	4 4 0	4 4 3	4 4 0	4 4 0
Arctic Grayling	Deeppass Bay	Value	292	284	1.14	2	<0.05 0.05	0.0004 0.073	<0.02 <0.04	0.37 2.28	<0.03 <0.03	0.1 0.119	<0.02 <0.04	0.21 2.6	4.89 24.98
		N	1	1	1	0 1(1)	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1

\* Mode: Most frequently found stage of maturity; N: total sample size (total at the modal value)

\*\* Age was determined with scales for this fish, other ages were estimated from otoliths

tailings, as well as Trout Lake, a relatively pristine lake (DFO unpublished data and Swyripa et al., 1993).

Cadmium, copper, lead, selenium, nickel and zinc concentrations in Port Radium and Deerpass Bay fish muscle and liver were consistent with concentrations observed in other fish and can be regarded as background levels (Lafontaine, 1994). Concentrations of arsenic in lake trout and lake whitefish muscle tissues appear slightly greater than concentrations observed in the pristine Trout Lake fish. Hepatic arsenic data were not available for Trout Lake.

Mercury concentrations in Port Radium and Deerpass Bay fish were relatively low.

Concentrations in Port Radium lake trout muscle tissue varied between 0.027 and 0.197 ppm and between 0.119 and 0.239 ppm in Deerpass Bay samples.

Differences were noted between metal concentrations in fish liver and in muscle tissue. Arsenic, mercury and nickel concentrations were similar in the two tissues. Concentrations of cadmium, copper, selenium and zinc were more elevated in the liver tissue. A more detailed data analysis will be done to establish statistical relationships.

## **REPORTS GENERATED**

Lafontaine, C.N. 1994. Port Radium - Deerpass Bay 1993: Field Methods, Analytical Methods and Evaluation of Metal Data. September 1994 Draft.

## **REFERENCES**

Kalin, M. 1982. Port Radium, Northwest Territories, An Evaluation of Environmental Effects of the Uranium and Silver Tailings, 1982.

Hatfield Consultants Ltd. 1985. An Evaluation of Environmental Conditions Associated with the Abandoned Uranium Mines at Rayrock and Echo Bay.

Swyripa, M.W., C.A. Lafontaine and M.C. Paris. 1993. Water and fish quality from Trout Lake., NWT, 1990-1991.



## **5.0 PREDICTIONS, FORECASTING AND MODELLING ISSUES**

### **5.1 UPDATE OF ICE JAM FLOOD DATABASE**

#### **PROJECT COORDINATOR**

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#### **CONSULTANT**

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#### **PROJECT OBJECTIVES**

1. To update the surveyed ice jam water surface profiles and high water marks data of Hay River during the 1992 break-up;
2. To update the probability analysis of break-up levels with 1988-1992 data; and
3. To compare the 1992 flood levels with other years.

#### **DESCRIPTION**

The Town of Hay River lies at the mouth of the Hay River on the southwest shore of Great Slave Lake (Figure 1). A significant portion of the town is located on a low-lying delta, which consists of one main island, Vale Island, bounded by the East and West Channels. Because of its location in a cold region and at a river mouth, the Town of Hay River is threatened almost every year by ice jams that form at break-up against the thick, solid ice of Great Slave Lake. The occurrence of these ice jams usually coincides with peak snowmelt runoff. As a result, some degree of flooding can be expected almost every year. Severe flooding, however, occurs on the average of once every eight years. The last such flood occurred in 1985.

To illustrate the magnitude of the flooding in the West Channel, Table 1 presents annual flood elevations and total damages (1993 dollars). These calculations are not possible for the East

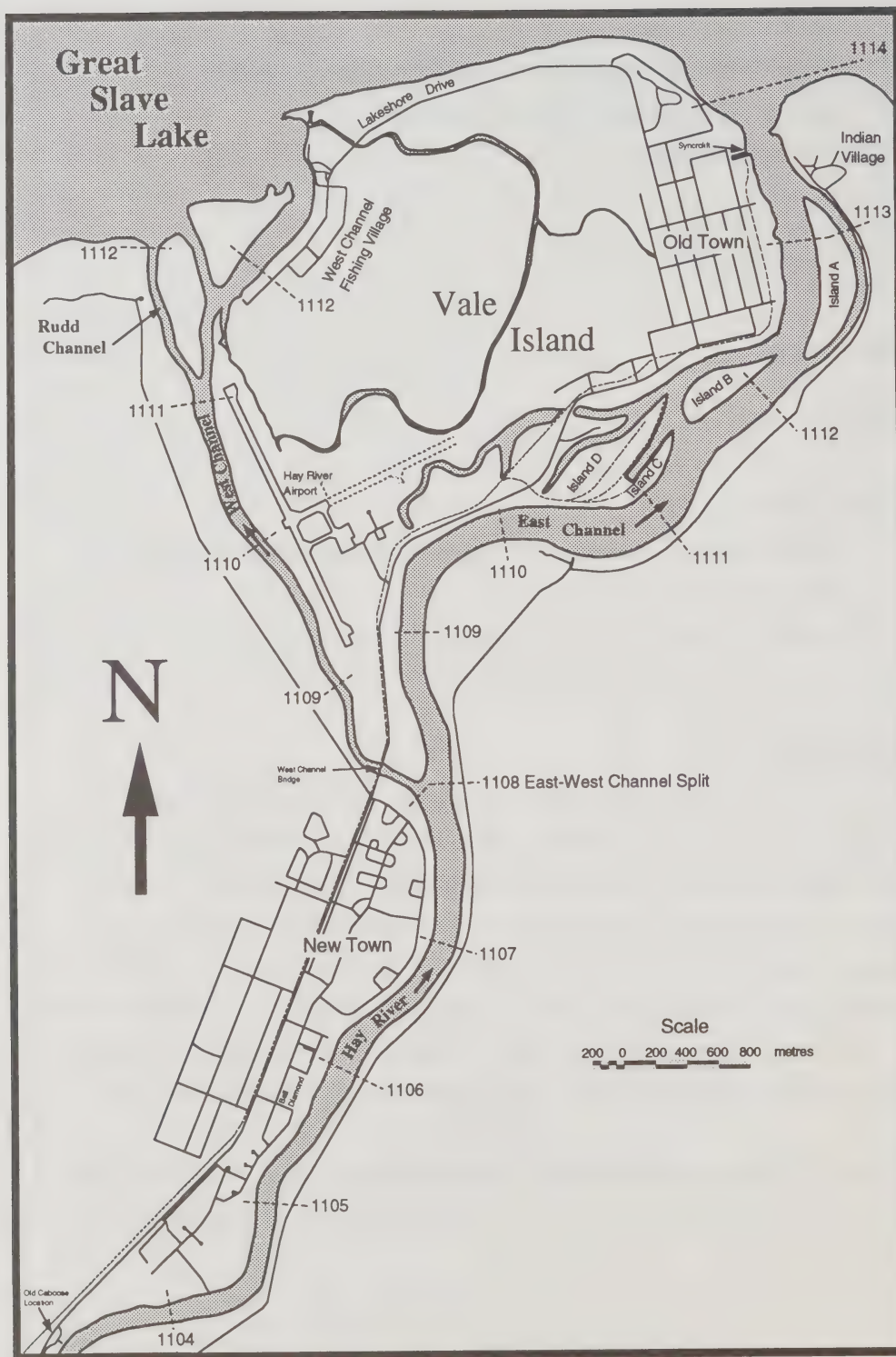


Figure 1. Map of the Hay River Delta showing salient features and distances along the river from the source in Kilometres.

Channel because flooding is less frequent and more difficult to quantify than for the West Channel. However, the potential for significant damage to the East Channel is greater because it is more developed.

**Table 1. Summary of flood damages for the West Channel Village.**

Year	Flood Elevation (metres)	Damages in 1993 \$
1985	159.9	\$1,259,207
1986	159.0	\$59,853
1987	158.1	\$0
1988	158.5	\$0
1989	158.7	\$21,600
1990	157.6	\$0
1991	157.0	\$0
1992	159.1	\$15,759
1993	n/a	n/a

Source: Jasek 1993 unpublished

The total damage in 1993 dollars for the eight-year period was approximately \$1.36 million. Based on this information, the estimated damage for the West Channel alone is in the order of \$86,000 annually.

In 1987 Indian and Northern Affairs Canada and Environment Canada initiated an assessment of ice break-up on Hay River. A large portion of this work, namely the historical probability analysis and the development of a forecast procedure, was performed by the University of Alberta. Under AES funding, information was compiled on ice jam water surface profiles, discharge rates, break-up sequences and high-water marks. The purpose of this data collection was to calibrate a model to establish a flood zone delineation area and to provide information on

the timing and severity of surges reaching the town of Hay River.

### **ACTIVITIES IN 1993**

High water marks and water level surveys conducted at Hay River in 1990, 1991 and 1992 were reduced and compiled. High water marks in 1992 were graphically presented and compared to high water marks of 1963, 1985 and from 1987 to 1991. The probability analysis used to establish flood zone delineation areas for the town of Hay River was also updated to include recent floods from 1988 to 1992. All data, including water temperatures and the melt rate of the ice jam head taken from 1987 through 1992, were presented in tabular form.

### **RESULTS**

Data are tabulated and presented in Jasek et al., 1993.

Comparison between the 1992 flood and other years show that the 1992 flood was the third largest in the West Channel Village of Hay River with only 1985 and 1974 floods exceeding it. The 1992 flood was also the third largest in the East Channel with floods in 1963 and 1914 exceeding it. A comparison of the three highest West Channel Village high water-mark profiles showed a very similar shape, suggesting that it may be possible to model these levels.

### **CONCLUSIONS AND FUTURE DIRECTIONS**

Compilation of data in this report has been worthwhile as several significant floods have occurred during the last five years (1989 - 1992). The additional data collected in this study did not change the flood probability distributions significantly, but the reliability of the analysis has been increased, especially in the West Channel where the historical record was quite short.

The flood which occurred in 1992 was a significant event for both the East and West Channels. This event reinforced the belief that the risk to life and property still exists in the town of Hay River.

## **PUBLICATIONS AND REPORTS GENERATED**

Jasek, M. 1993. Hay River Flood Control, Hay River, NWT. Report completed for the town of Hay River, December 1993.

Jasek, M., S. Stanley and R. Gerard. 1993. Update of Ice Jam Flood Database, Hay River, NWT. Report prepared for DIAND, Yellowknife, NWT.



## **5.2 A CORRECTED PRECIPITATION ARCHIVE FOR THE NORTHWEST TERRITORIES<sup>1</sup>**

### **PROJECT COORDINATORS**

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Atmospheric Environment Service  
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John Metcalfe  
Canadian Climate Centre  
Atmospheric Environment Service  
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### **PROJECT OBJECTIVE**

To provide a record of precipitation values for the NWT and Mackenzie River Basin that has been corrected for biases in measurement method and wind-induced error.

### **INTRODUCTION**

Precipitation plays a key role in the hydrological cycle. The Canadian Global Energy and Water Cycle Experiment (GEWEX) programme clearly identifies precipitation as one of the principle components in hydrological modelling and process studies. Yet, it is also acknowledged that there can be significant errors in the measurement of precipitation, particularly cold season precipitation. These errors must be documented, and where possible, corrected if a long-term compatible, consistent data set is to be available for these types of climate system studies.

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<sup>1</sup>Editors' Note: This paper consists of an extract from "A Corrected Precipitation Archive for the NWT" by J.R. Metcalfe, S. Ishida and B.E. Goodison, Climate and Atmospheric Research Directorate, Downsview. Report produced for Water Resources Division, DIAND, Yellowknife

The inherent nature of snow cover (eg. highly variable temporal and spatial structure related to land cover and terrain and redistribution by wind) and of snowfall (varying density, significant errors in gauge measurements due to wind, wetting and evaporative losses) make snow more difficult to measure accurately than rainfall. In Canada, the problem of precipitation measurement is even more difficult because snowfall accounts for about 30% of the total precipitation, and in northern regions, such as the NWT, the snowfall component increases from 60 to 70% of the total annual precipitation, with snowfall potentially occurring in every month. The Atmospheric Environment Service has been actively involved both nationally and internationally in quantifying precipitation measurement errors and developing improved methods for snow measurement and analysis (e.g. Goodison 1978, 1981; Goodison and Louie, 1986; Goodison and Metcalfe, 1989, 1992; Metcalfe and Goodison, 1993). Recently, the World Meteorological Organization (WMO) has completed the Solid Precipitation Measurement Intercomparison (Goodison et al., 1994), which has allowed Canada and other countries to define the systematic errors resulting from wind, wetting and trace amounts.

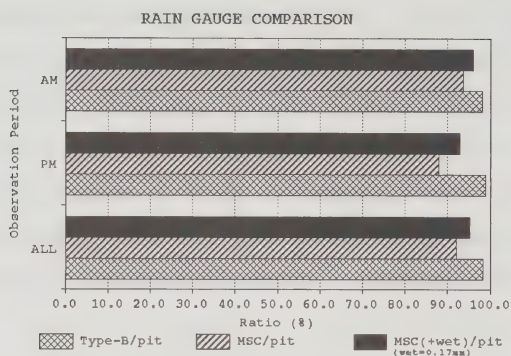
The Atmospheric Environment Service presently collects precipitation data at about 65 stations in the NWT. Water Survey of Canada measurements of the run-off from certain basins in the NWT located near selected Atmospheric Environment Service stations have shown that run-off is greater than is reported falling on the basins. As a result Atmospheric Environment Service, in collaboration with Indian and Northern Affairs (INAC), Water Resources Division, is undertaking the development of a corrected historical precipitation archive for selected NWT stations based on the results from recent national and international precipitation intercomparison studies.

## **CANADIAN PRECIPITATION MEASUREMENT METHODS**

Precipitation is measured in Canada at more than 2,400 Atmospheric Environment Service co-operative climate stations, resulting in an average precipitation station density of 25 stations per 100,000 km<sup>2</sup>. In the NWT, however, the density is closer to two stations per 100,000 km<sup>2</sup> and most stations still use non-recording or manual methods of measurement,

with an observer making the measurements. The Type-B rain gauge is used to measure rainfall at all of these stations. The Canadian Nipher Shielded Snow Gauge System is the standard Atmospheric Environment Service instrument for measuring fresh snowfall water equivalent at about 350 (30 in NWT) of these stations. The remaining stations estimate snowfall precipitation from ruler measurements of the depth of freshly fallen snow and by assuming the density of fresh snow to be  $100 \text{ kg m}^{-3}$ . A more complete discussion on the Atmospheric Environment Service network is given in Goodison et al. (1981), Goodison and Louie (1986) and Goodison and Metcalfe (1989). Precipitation errors fall within two broad categories: rainfall measurement errors; and snowfall measurement errors. These broad categories are discussed below.

**Rainfall measurement errors** - Goodison and Louie (1986) reported that the difference in gauge catch for the MSC and Type-B rain gauges compared to pit gauge measurements at three test sites in Canada averaged 4% low for the MSC and 1% low for the Type-B. Although these tests provided some basic information on the magnitude of the systematic errors compared to the reference pit gauge for three climatic regions, no interpretation of the differences was attempted. Both gauges are mounted relatively low to the ground to reduce the effect of wind on gauge catch. The Type-B gauge was designed to minimize systematic errors, particularly losses due to adhesion of water to the gauge surface, evaporation between measurement periods and splash out. Ongoing intercomparison of Atmospheric Environment Service rain gauges at the Centre for Atmospheric Research (CARE) near Toronto, Ontario confirms that the systematic difference between the Type-B gauge mounted at 40 cm and the pit gauge is about 2% lower at an open windy site (Fig. 1). Laboratory experiments and field investigations by Metcalfe and Routledge (1994) have shown that wetting and evaporative losses for the MSC gauge can be quite large. Wetting loss is defined as water subject to evaporation from the surface of the inner walls of the precipitation gauge after a precipitation event and water retained on the walls of the gauge and its containers after it is emptied. The average retention loss for the MSC gauge used prior to 1965, that is, all copper inserts, is 0.36 mm per observation. The average retention loss for the post- 1965 period, when the plastic insert was used, was only 0.17 mm.



**Figure 1. Comparison of MSC and Type-B Rain Gauges to Pit Gauge at the Centre for Atmospheric Research Experiments during 1993, for morning, afternoon and all observations.**

Although it is estimated that evaporative losses can also be significant for this gauge, it is difficult to measure and for principal and synoptic stations it is probably small since observations are made at shorter intervals than at climatological stations. Figure 1 compares the catch of the MSC with plastic insert and Type-B rain gauges to the pit gauge at CARE and also shows the effect of correcting the MSC gauge for wetting loss. Even with correction for wetting loss the MSC gauge measured an average of 5% below the pit gauge. CARE is a climate station which makes two observations a day (i.e. am and pm). There is a noticeable difference in measured MSC totals compared to the pit gauge between morning and afternoon observations. The lower ratio for the pm observation could be due to evaporation, but this has not been confirmed by any experimental studies.

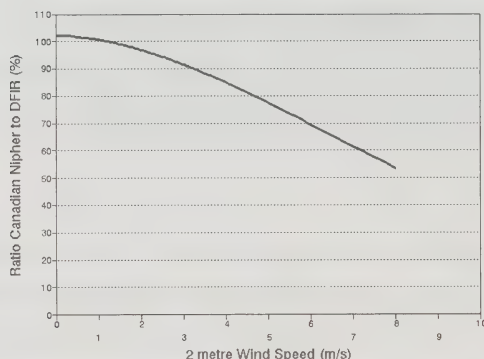
**Snowfall measurement errors** - Before 1960, all Atmospheric Environment Service stations relied on snow ruler measurements to estimate fresh snowfall precipitation. Goodison (1981) and Goodison and Metcalfe (1981) showed that this method can be subject to substantial error. For an individual event the error depends on the magnitude of

the deviation in the true density from  $100 \text{ kg/m}^3$ , the representativeness of both the site and the depth measurements, and the time of the observation during the snow storm. Recent results from Dease Lake, British Columbia, an evaluation station in the WMO Intercomparison and a study site in the fresh snowfall experiment, produced a mean density of  $81 \text{ kg/m}^3$  which was calculated from comparative reference gauge/ruler ratios over five winter seasons. This value corresponded favourably to average densities of 71 to  $84 \text{ kg/m}^3$  determined in a previous study (Goodison and Metcalfe, 1981). Use of the standard  $100 \text{ kg/m}^3$  mean density at this station, therefore, results in a 20% overestimation of winter precipitation.

The Canadian Nipher Shielded Snow Gauge System has been designated as the standard Atmospheric Environment Service instrument for measuring snowfall amount as water equivalent. The accuracy of this snow gauge and others used in Canada was first defined by Goodison (1978). Results from the WMO Intercomparison indicate results similar to those found previously and show the catch of the Canadian Nipher Shielded Gauge to be almost the same as the WMO reference standard (Goodison and Metcalfe, 1992). As the melted contents are poured from the gauge to a measuring graduate, there is a wetting loss as the gauge always retains a certain amount of water that cannot be poured out. Previous field experimentation (Goodison, 1978) determined an average wetting loss for the Nipher gauge collector of  $0.15 \text{ mm} \pm 0.02 \text{ mm}$ . Recent studies (Goodison and Metcalfe, 1989), as part of the WMO Intercomparison experiment, confirm these findings, with older collectors showing even greater wetting loss. This is a systematic error which occurs every time the contents are melted and poured out of the gauge.

The measurement of trace amounts of precipitation ( $<0.2 \text{ mm}$ ) using the Nipher gauge is also a concern. Some Arctic stations have reported over 80% of all precipitation observations as trace amounts. A trace is assigned a value of zero in the Atmospheric Environment Service digital archive. Using techniques similar to those described above for resolving wetting loss, it was determined that a trace could be an actual measurable amount, the value of which lies between  $0.0 \text{ mm}$  and  $0.15 \text{ mm}$ . For correction purposes a trace

reported in any six-hour period is assigned a value of 0.07 mm. In the Arctic, where there is a high incidence of ice crystals reported, each trace is assigned an even lower value of 0.03 mm. Woo and Steer (1979) suggested similar values for Arctic trace rainfall.



**Figure 2 .Gauge catch ratio as a function of wind speed for the Canadian Nipher Shielded Snow Gauge System.**

Many investigators have indicated that wind is a major cause of error in precipitation gauge measurements (Goodison et al., 1981). The effect of wind on gauge catch can be reduced by the use of naturally sheltered locations, or by using artificial shielding. Goodison (1978) showed that for most gauges, the mean ratio of gauge catch to "true precipitation" as a function of wind speed decreases exponentially with increasing wind speed. The Canadian Nipher Shielded Gauge was an exception. The unique design of the Canadian Nipher Shielded Gauge minimizes disturbance of the airflow over the gauge and eliminates updrafts over the orifice. This results in an improved catch by the gauge, for wind speeds up to 7 metres/second, measured at gauge height, relative to other shielded and unshielded gauges (Goodison et al., 1983). Results from the WMO Intercomparison, shown in Figure 2, confirm Goodison's findings but show the catch efficiency of the Nipher to be generally lower than that reported by Goodison (1978). Considering that two quite different methods

of determining "true precipitation" were used and that the WMO Intercomparison involved sites in several different climatic regions, the results from these two studies are quite comparable.

## **AES PRECIPITATION ARCHIVE CORRECTIONS**

Information in the Atmospheric Environment Service archive is stored as separate elements. For precipitation, the quality controlled elements which are archived include: each six hour precipitation measurement; 24-hour rainfall (i.e. millimetres of rainfall from rain gauge measurement); 24-hour snowfall (i.e. centimetres of fresh snowfall depth from ruler measurement); and, 24-hour precipitation total (i.e. millimetres of water equivalent from either, or both rain gauge and Nipher gauge measurement). Because the type of precipitation for each six hour amount is not identified, it is impossible to determine accurately the gauge used to make measurements when mixed precipitation (i.e. rain and snow) occurs. This prevents assigning the exact wetting loss correction for gauge type during these events. In cases such as these, if the 24-hour snowfall is not greater than 50% of the 24-hour precipitation total (i.e. rainfall is greater than snowfall) then no correction is applied to the six hour precipitation values for wetting loss or wind induced error. Six-hour trace amounts, for rain and/or snow are identified as trace, but are given an absolute value of zero in the archive when calculating monthly precipitation totals. These events are assigned a value of 0.07 mm or in the case of Arctic stations 0.03 mm. No further correction is applied to trace events.

For wind speed, the element used is the reported hourly wind speed measured as a two-minute average recorded on the hour. From these, the mean wind speed for the six-hour period corresponding to the time of the precipitation observation is determined. The station wind speed, which is typically located at 10 m above ground surface, is then estimated for a Canadian Nipher Shielded Gauge orifice height of 1.5 m according to the following formulae:

$$U_{hp} = (\log hz_o^{-1}) (\log Hz_o^{-1})^{-1} (1 - 0.024\alpha) U_H$$

where:

$U_{hp}$	wind speed at the height of the gauge orifice
$h$	height of the gauge orifice above ground, Nipher=1.5 m
$z_o$	roughness length: 0.01 m for winter
$H$	height of the wind speed measuring instrument above ground, normally 10 m
$\alpha$	average vertical angle of obstacles around the gauge
$U_H$	wind speed measured at the height $H$ above ground

The latter depends on the exposure of the gauge site and is based on a technique for classifying exposure of a site as recommended by Sevruk (1994) using station descriptions stored in the Atmospheric Environment Service archives.

To adjust snow water equivalent (SWE) measurement at Atmospheric Environment Service stations for periods prior to Nipher gauge measurements, a mean density is calculated based on the ratio of corrected Nipher gauge measurement to snowfall measurement for storms of 5.0 mm or greater during the period of record when snow ruler and gauge measurements were made coincidentally. This calculated density is then used to go back and correct the 24-hour precipitation total amounts prior to gauge measurement. To correct Atmospheric Environment Service stations that have only snow ruler measurements (i.e. no Canadian Nipher Shielded Gauge), average regional densities based on the above procedure will be used to interpolate new average station density. Table 1 shows average snow densities for different climatic regions within the NWT derived by this method.

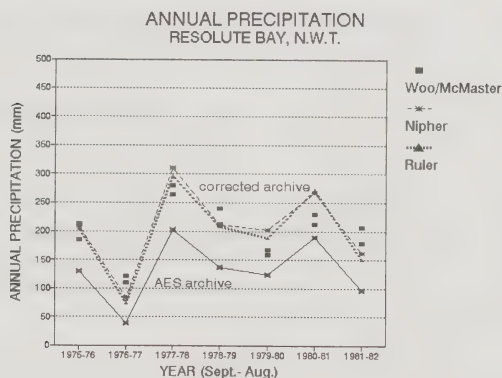
**Table 1. Mean snowfall densities used to calculate SWE from ruler measurements of snow depth.**

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High Arctic	108 kg m <sup>-3</sup>
NWT barrens (east of longitude 110°)	145 kg m <sup>-3</sup>
NWT barrens (west of longitude 110°)	137 kg m <sup>-3</sup>
Mackenzie (delta area)	106 kg m <sup>-3</sup>
Mackenzie (Norman Wells to Great Slave Lake)	112 kg m <sup>-3</sup>
Baffin Island	125 kg m <sup>-3</sup>

## SUMMARY

Figure 3 compares the present archived annual total precipitation measured at Resolute Bay, NWT with the corrected total obtained using the above method. Plotted with these are adjusted annual precipitation amounts based on special snow surveys reported by Woo et al. (1983). Both the corrected annual precipitation and the snow course totals exhibit good agreement. Most important, however, is that both methods indicate that actual annual precipitation is 50 - 100% greater than measured at this station. Similar increases resulted when precipitation corrections were made at other Arctic stations. Increases in corrected annual precipitation totals were less dramatic for other NWT stations located south of 65°N. For example, at Yellowknife corrections increased average annual precipitation by 26% and at Norman Wells by 19%. Both these sites are more sheltered than Resolute and the effect of wind on gauge catch is less.



**Figure 3.** Comparison of archived and corrected annual total precipitation measurements and annual precipitation estimates (range) from special snow survey data (Woo et al., 1983) at Resolute Bay, NWT.

The primary reason for the larger differences between measured and corrected precipitation at High Arctic stations is the number of traces recorded annually at these locations. At Resolute Bay the average number of traces recorded each year has continued to increase from around 300 in 1950 to well over 700 in 1993. A large number of these trace observations are a result of the occurrence of ice crystals. There is some speculation that this trend in ice crystal occurrence may be directly or indirectly related to a systematic increase in Arctic haze and to changes in the Arctic winter boundary layer (Bradley et al., 1993).

The major source of water in NWT basins is precipitation. To estimate flows and to regulate the construction of holding ponds, accurate input values of all environmental parameters to the water balance equation must be available to users in both industry and government. The correction of six hourly archived precipitation measurements for known systematic errors will provide significantly improved estimates of actual precipitation than are currently available. It is anticipated that anomalies currently existing between various hydrologic data sets will be minimized after correction of the precipitation archive.

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## **6.0 EDUCATION**

### **6.1 FIRST NATIONS DRINKING WATER VIDEO PROJECT**

#### **PROJECT COORDINATOR**

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Indian and Northern Affairs Canada  
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#### **CONSULTANT**

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#### **PROJECT OBJECTIVE**

To produce a video for distribution that addresses current Yukon drinking water concerns.

#### **DESCRIPTION**

Many Yukon First Nation communities are concerned about the provision of safe drinking water. Water Resources Division is frequently contacted with questions ranging from "Why do we need to use chlorine?" to "Why do we need a well, can't we drink the water from the river like before?" It is important for the Water Resources Division to act quickly and provide clear, understandable and concise answers to these questions.

A video was suggested as an education tool. In this way, all drinking water issues could be addressed in a single format. Another benefit of a video is that it can present a large amount of information in an appealing and easy-to-understand format. The Yukon drinking water video was produced in conjunction with the Canada Communications Group, the Yukon Territorial Government and the Council for Yukon Indians.

The video production focused on traditional aspects of water use and the need for disinfection or treatment to insure the safety of water for consumption. The basic difference between surface and ground water supplies was highlighted and an examination of the potential natural and anthropogenic sources of contamination followed. The video also examined differences between municipal water supplies and self-collected supplies. Sources of microbial contamination were reviewed as well as the use of chlorine or boiling to produce safe drinking water. The video conveyed two clear messages: the source of microbial contamination is likely natural; and all drinking water should be treated prior to consumption.

#### **ACTIVITIES IN 1994**

Production began in 1993 and was completed in 1994. The finished video was distributed to Yukon First Nation communities, the Council for Yukon Indians, public libraries and other public facilities upon request. Additional copies have been distributed to Nebraska Indian Affairs, Health Canada, the American Water Works Association, Canadian Water Works Association and a research facility in the Republic of China.

## **6.2 TEACHING RESOURCES ON WATER EDUCATION FOR SECONDARY SCHOOLS IN THE NORTHWEST TERRITORIES**

### **PROJECT COORDINATOR**

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### **CONSULTANT**

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### **PROJECT OBJECTIVE**

To develop a teachers' resource package on northern water resources that is suitable for use throughout the Northwest Territories at the grade 10-12 level.

### **DESCRIPTION**

This project addresses the public's increasing awareness of a wide variety of water-related environmental issues in the NWT and the new high school curriculum that emphasizes a Science, Technology and Society approach to such issues.

The resource package contains seven teaching units designed to provide the necessary information to help teachers and students understand northern water systems and issues as well as promote the maintenance of water resources in the NWT. The seven teaching units include the following sections:

1. A Peculiar Substance: Properties of Water;
2. The Lifeblood of All: Water's Role in Regional Processes;
3. Our Watery Home: Aquatic Ecosystems;
4. Water Uses and Values;

5. Water Conservation and Management;
6. Water Quality and Quantity; and
7. Global Connections.

In addition to these seven units, the resource package includes an appendix, an aquatrivia, a glossary and introductory notes for teachers and resource people.

### **ACTIVITIES IN 1994**

A resource inventory and an identification of needs were completed in 1993-94 to initiate this project. A writing workshop on water was also held to gather ideas and information needs from representatives of the various school boards of the NWT. A draft package was produced for review initially by the departmental representative and the educational advisory before a more comprehensive review by teachers for technical and educational accuracy.

The final product will be ready for the 1995 fall semester.

### **FUTURE DIRECTIONS**

This product has strong links to the contaminant curriculum work being administered by the Métis Nation. The teachers' resource package could be used in the Yukon Territory and Northern Quebec. The Government of Alberta has also expressed an interest in this package.

### **PUBLICATIONS AND REPORTS**

Cygnus Environmental Consulting and Strong Interpretation, 1994. *Take the Plunge: Teaching Resources on Water Education for Secondary Schools in the Northwest Territories*, prepared for the Water Resources Division, Indian and Northern Affairs Canada.







